EXHIBIT 2

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF NEW JERSEY

IN RE: JOHNSON & JOHNSON TALCUM POWDER PRODUCTS MARKETING, SALES PRACTICES AND PRODUCTS LIABILITY LITIGATION ***THIS DOCUMENT RELATES TO ALL CASES***	**MDL NO. 16-2738 (FLW) (LHG)**

EXPERT REPORT OF LAURA WEBB, PHD FOR GENERAL CAUSATION *DAUBERT* HEARING

Date: February 25, 2019

Laura Webb

Laura Webb, Ph.D.

Evaluation of the Formation of Talc Ores in the Fontane, Southern Vermont and Guangxi Talc Mines

1.0 Executive Summary

I have been asked to prepare a report focused on the scientific principles that govern the formation of mineable high-grade talc deposits used in the manufacture of Johnson's Baby Powder and Shower to Shower, and to investigate the possible relationship of such deposits, or lack thereof, to amphibole asbestos. This charge includes evaluating plaintiffs' experts' reports by Dr. Cook and Dr. Krekeler, and addressing differences in the formation of amphibole minerals with different crystal habits (e.g., asbestiform vs. prismatic) and the physical and chemical properties that impact biopersistence and toxicity.

Based on my review of materials, my educational background and professional experience as a geologist, my expert opinions are provided below with a reasonable degree of scientific certainty. My main conclusions are as follows:

A. Plaintiffs' experts' reports fail to appropriately synthesize key data and observations available in the peer-reviewed scientific literature that are pertinent to understanding the issues in this litigation. The body of evidence in the published scientific literature does not support the assertion that there is/was asbestos in cosmetic-grade talc deposits mined for use in Johnson's Baby Powder and Shower to Shower; nor do geologic principles suggest that there should be, based on a review of the local and regional geologic data.

B. Talc is a common metamorphic mineral in metamorphosed ultramafic and carbonate rocks. However, mineable high-purity talc deposits are the result of special cases of intense metasomatism (an uncommon form of metamorphism discussed below in Section 4.0) in which the chemical composition of an original rock is changed to something closer to that of the talc mineral composition. The conditions associated with this transformation to create the talc ores mined for Johnson's Baby Powder and Shower to Shower were not amenable to asbestos formation.

C. There is no well-founded, scientifically-sound evidence in the peer-reviewed scientific literature for an association of amphibole asbestos with the talc deposits of concern. Based on reviews of the geology associated with the applicable mines, and the pressure and temperature histories recorded by the rocks, any amphibole found in Johnson's Baby Powder and Shower to Shower derived from the Fontane, southern Vermont and Guangxi talc mines would likely be incidental actinolite or tremolite cleavage fragments from non-asbestiform amphiboles most likely derived from the margins (blackwall zones) of the talc deposits.

D. Amphibole cleavage fragments are, in general, much less chemically-resistant and have different surface chemistries than their asbestiform counterparts, for which other distinctive properties include flexible bundles of fibrils (typically less than 0.5 microns in diameter) with high tensile strength.

2.0 Summary of Qualifications

I am a geologist who specializes in using the tools of petrology (the origin and evolution of rocks discerned from mineralogical evidence), structural geology (interpreting rock deformation) and geochronology (radiometric dating) to understand the histories of rocks and regions. I obtained my Bachelor of Science in Geology from the University of California at Los Angeles in 1993 and my Ph.D. in Geological and Environmental sciences from Stanford University in 1999 (see CV attached as Exhibit A). After a postdoctoral appointment at the University of Geneva in Switzerland from 1999–2000, I moved to Syracuse University in New York, where I was a geochronology laboratory manager from 2000–2008 and held a Research Assistant Professor appointment from 2004–2012. In the fall of 2008, I began my career

at the University of Vermont (UVM) as a tenure-track faculty member in the Department of Geology. In 2014, I was promoted with tenure to Associate Professor. I am a member of the following professional societies: Geological Society of America, Mineralogical Society of America, American Geophysical Union, Vermont Geological Society and the American Association for the Advancement of Science.

Beginning with my early academic training as a geologist, I have worked extensively in regions with complex geologic histories, such as those in Italy, Vermont and China. Based on prior research projects and/or themes, I have familiarity with the regional geology of the Fontane and Guangxi mine regions and have experience working near the southern Vermont mines. I have (co)authored 33 peer-reviewed scientific papers (32 published and one currently in press) with an additional two manuscripts currently in revision or review. A common theme is the integration of microscopic-scale observations of the relationships between mineral growth and deformation with outcrop data and regional geological and geophysical data (e.g., Webb et al., 1999, 2010, 2014). These data facilitate understanding of the pressure-temperature-time-deformation history of rocks and the resulting implications for the tectonic evolution of regions. My teaching at UVM spans the scope of disciplines I employ in my research and includes those that are essential to a holistic understanding of the formation of talc deposits and assessing any possible relationship to asbestos. Such courses include Petrology, Microstructures, Geochronology and Tectonics.

I am being compensated at the rate of $450 per hour for my expert work.

3.0 Minerals: Definitions and Important Concepts

Rocks are composed of one or more minerals. Minerals are naturally occurring inorganic compounds defined by their chemical compositions and unique crystalline structures. Minerals are classified based on these properties. In the case of talc deposits, geologists are mostly concerned with carbonate and silicate minerals that incorporate CO_2 and SiO_2 in their crystal structures. The mineral talc is a phyllosilicate (Figure 1), or sheet silicate, with the idealized chemical formula of $Mg_3Si_4O_{10}(OH)_2$.

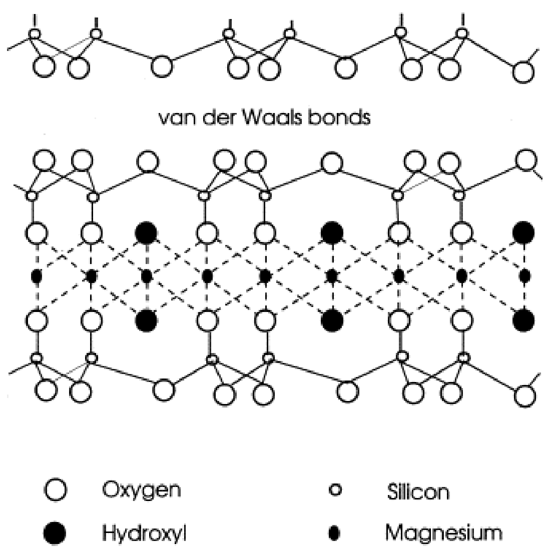


Figure 1. *Ball and stick model of the crystal structure of the mineral talc (from Huang and Fuerstenau, 2001). Talc sheets consist of Si tetrahedral, Mg octahedral, and Si tetrahedral layers (T-O-T). Weak van der Waals bonds hold the T-O-T sheets together, giving talc its platy habit.*

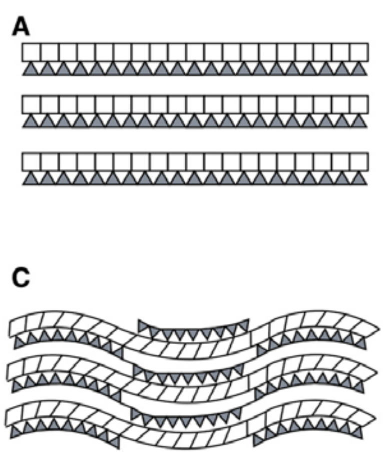
Many minerals can exhibit solid solution (i.e., be uniform solid mixtures), where cations (positively charged ions) with similar size and charge may substitute for one another in a mineral structure, allowing for known ranges in chemical composition for a given mineral. For example, forsterite is the pure magnesium-rich end-member of the mineral olivine (Mg_2SiO_4), and fayalite is the iron-rich end-member (Fe_2SiO_4). Almost all olivine found in nature contains some Fe and Mg and is thus a solid-solution of these two compositional end-members. Likewise, A small amount of Fe may substitute for Mg in talc crystals depending on various variables, including the chemistry of the geologic system and the pressure and temperature under which mineral formation and/or recrystallization occurs.

Structure and chemistry control all physical characteristics of a mineral, such as density, strength, mineral habit, cleavage, color and chemical stability. Habit is a term that refers to the general shape of the mineral, which is a function of the crystallographic structure as well as the conditions of formation. Table 1 defines common habit terms. Cleavage refers to weak planes in a crystal structure that influence how minerals break and controls the shape of crystal fragments. Cleavage planes may be described qualitatively as perfect, good, poor or indiscernible (synonyms may also be used). For example, talc crystals typically exhibit a platy or plate-like habit and have perfect cleavage along one crystallographic plane. This cleavage corresponds to the planes of weak van der Waals bonds (Figure 1). In other words, when forces are applied to talc crystals, the strongly-bonded T-O-T sheets remain intact and slip will occur along the weak forces of attraction between the sheets. This property is what gives talcum powders a slippery feel.

Table 1. *Examples of common terms used to describe mineral habits.*

Term	Definition
Acicular	Needle-like appearance, visible to naked eye.
Asbestiform	Having the habit of asbestos, including: "fiber-like morphology and dimensions; enhanced strength and flexibility; diameter-dependent strength; increased physical and chemical durability; and improved surface structure (i.e., relatively free of defects)." (NRC, 1984).
Bladed	Long, flat and thin.
Blocky or equant	Roughly equidimensional (e.g., boxy).
Fibrous	The appearance of clusters of minerals with long aspect ratios, often parallel to one another or radiating, that may or may not be separable. Often used synonymously with terms such as acicular, asbestiform and filiform.
Massive	No clear structure or dominant shape apparent.
Filiform or capillary	Thread-like appearance.
Platy	Sheet-like appearance.
Prismatic	Elongate with faceted sides.
Tabular	Having a rectangular shape and relatively thin or with moderate thickness.

Serpentine refers to a subgroup of phyllosilicates that includes about 20 minerals, including antigorite, chrysotile and lizardite (Rakovan, 2011). Serpentine minerals are 1:1 layer silicates. While the chemical formulas may be similar, Figure 2 illustrates how each has a unique crystal structure, making each a distinct mineral. Lizardite tends to most commonly occur as small (micron-scale) platy or elongate mineral



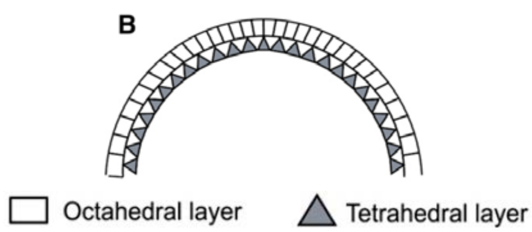


Figure 2. *Schematic representations of the serpentine minerals (A) lizardite, (B) chrysotile, and (C) antigorite. Images from Lacinska et al. (2016). Tetrahedral layers are composed of silicon (Si) and oxygen (O), whereas the octahedral layers include magnesium (Mg), O, and hydrogen (H). While compositionally similar, the ways in which atoms are bonded result in varying crystal structures: flat lizardite sheets, cylindrical chrysotile, and modulated antigorite. A small mismatch in the size of the octahedral and tetrahedral sheets in chrysotile results in the mineral's characteristic cylindrical shape.*

grains, antigorite tends to form coarser grained (millimeter-scale) flaky crystals, while chrysotile (serpentine asbestos) forms long hollow scrolls or cylinders with maximum outer diameters on the order of 150 angstroms (~0.015 microns) (Evans, 2004).

Amphibole minerals (Figure 3 [p. 5]) are members of the inosilicates that can exhibit a range of compositions (i.e., solid solution) (Table 2 [p. 6]). Which amphibole(s) are present in a rock (e.g., actinolite or anthophyllite) depend on the chemistry of the rock and its geologic history. Likewise, whether an amphibole is prismatic or asbestiform is strongly dependent on pressure and temperature, volume and composition of fluids and the deformation history of the rock at the time of its formation. Details relevant to these topics are discussed in subsequent sections of this report.

In cases where the amphibole crystal shape is well developed (i.e., prismatic), amphiboles are typically hexagonal in cross-section (Figure 3b). In general, amphiboles have two good cleavages that coincide with the {110} crystallographic planes (labeled in Figure 3b). Figure 3c illustrates how, in cross-section, these cleavage planes intersect in a diamond shape (see also upper left image in Figure 4 [p. 8]) and that the long axis of cleavage fragments are typically parallel to the c-axis of the mineral.[1]

While asbestiform minerals may be called fibrous, fibrous is not exclusively synonymous with asbestiform. The term fibrous is frequently used many ways by scientists, often applied to mineral habits with long aspect ratios that range in form from bladed to acicular to asbestiform (Zoltai, 1978; Ross et al., 2008; Belluso et al., 2017). Several different regulatory definitions also exist and must be distinguished as such (see summary in Wylie and Candela, 2015). For example, elongate mineral particle (EMP) has been employed as a term encompassing all structures with aspect ratios greater than 3:1, and therefore does not discriminate between asbestos and cleavage fragments (Kelse and Thompson, 1989). To further confound the issue, while asbestiform-amphibole-bearing deposits or rock units may contain non-asbestiform amphiboles (e.g., Harper et al., 2015), it is not the case that non-asbestiform (i.e., common) amphibole-bearing rocks inherently contain asbestiform amphiboles.

In this report, I use the term amphibole asbestos to refer to the regulated forms of amphiboles[2] that grow in an asbestiform habit. Non-asbestiform amphiboles refer to all other habits, such as prismatic, acicular, bladed (note that the latter two terms may be used synonymously with fibrous by certain authors). The issue of how amphibole asbestos differs from non-asbestiform amphiboles is further addressed below.

[Figure 3 on next page]

[1] Three-dimensional objects are often described using x, y, z coordinates for three mutually-perpendicular axes. Minerals are described in terms of a, b and c axes because these axes have different angular relationships to one another in different crystal systems.

[2] Regulated amphiboles refer to asbestiform riebeckite (crocidolite), cummingtonite–grunerite (amosite), anthophyllite, tremolite and actinolite, for which federal standards exist for occupational exposure or product concentration limits.

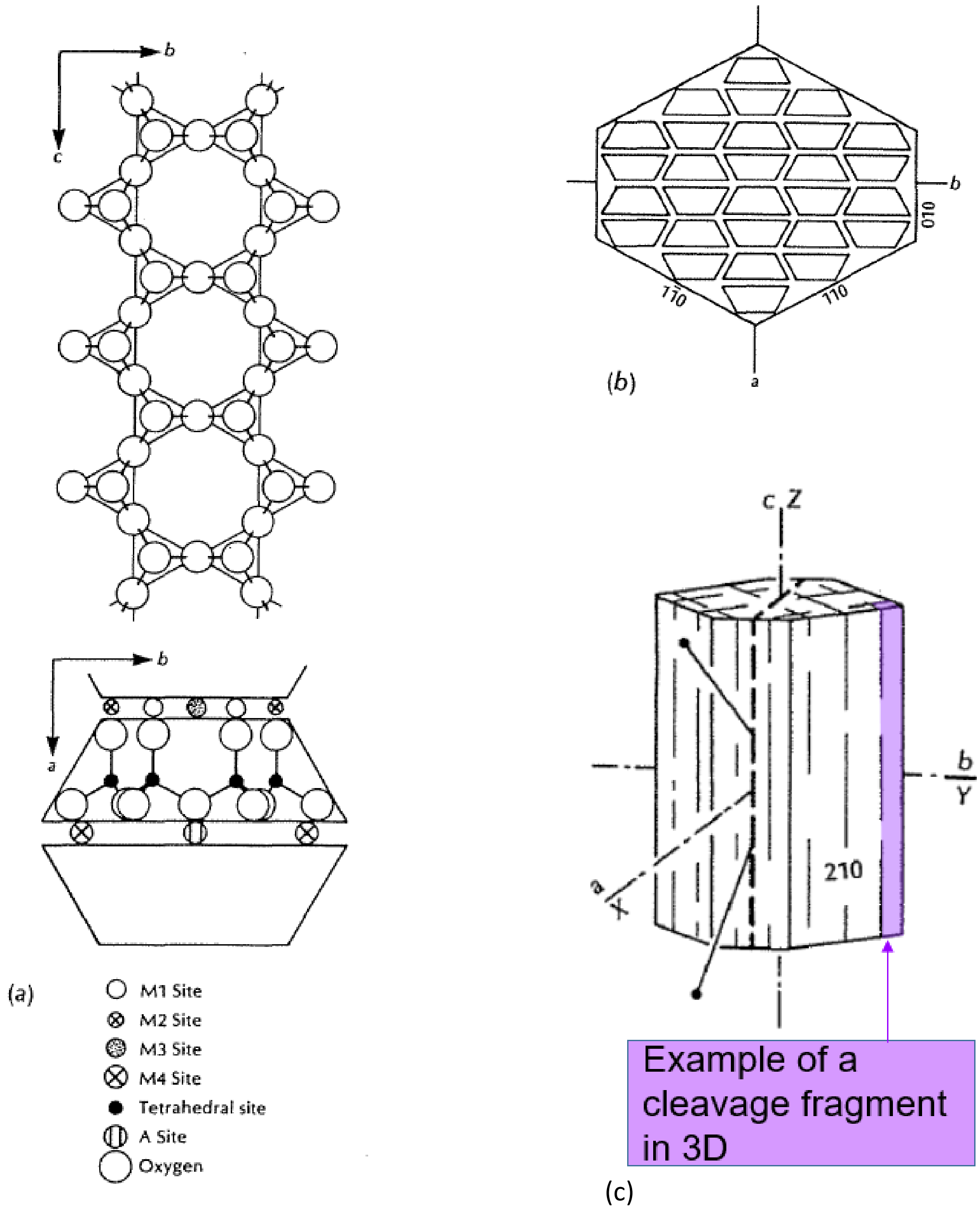


Figure 3. *Generalized amphibole crystal structure from Nesse (1991).* ***a)*** *Idealized double chain of tetrahedral (Si, O). The M1, M2, and M3 lattice sites correspond to elements associated with 'Y' as listed in Table 2, which are in octahedral coordination. Octahedral coordination means an atom is bonded with six neighboring elements or groups of elements (6-fold), defining the vertices of an octahedron. The M4 site corresponds to the elements associated with 'X' as listed in Table 2, which are in either octahedral or cubic (8-fold) coordination. The A site is a vacancy (empty site) in the amphibole structure.* ***b)*** *View down the c-axis of the crystal showing a typical amphibole cross-section (hexagonal). Amphiboles have two perfect cleavages that correspond to the {110} planes, forming diamond shapes in cross-section due to intersections forming ~120° and 60° angles.* ***c)*** *Three-dimensional view of an amphibole (anthophyllite) with the idealized crystal shape, showing a possible cleavage fragment with diamond-shaped cross-section (top) and long axis parallel to c-axis of the mineral. Another perspective is shown in Figure 4.*

Table 2. *Chemical formulas for minerals referred to in this report.*

Mineral	**Formula**
Talc	$Mg_3Si_4O_{10}(OH)_2$
Serpentine Group Chrysotile & lizardite; antigorite	$D_3[Si_2O_5](OH)_4$ D= Mg, Fe, Ni, Mn, Al, Zn $Mg_3Si_2O_5(OH)_4$; $Mg_{48}Si_{34}O_{85}(OH)_{62}$
Amphibole group Riebeckite (crocidolite) Cummingtonite-grunerite (amosite[a]) Anthophyllite Actinolite Tremolite	$AX_2Y_5((Si,Al,Ti)_8O_{22})(OH,F,Cl,O)_2$ A = ☐, Na, K, Ca, Pb^{2+} X = Li, Na, Mg, Fe^{2+}, Mn^{2+}, Ca Y = Li, Na, Mg, Fe^{2+}, Mn^{2+}, Zn, Co, Ni, Al, Fe^{3+}, Cr^{3+}, Mn^{3+}, V^{3+}, Ti, Zr ☐ *= Vacancy: Empty A site in the amphibole structure* ☐$Na_2(Mg, Fe^{2+})_3Fe^{3+}{}_2Si_8O_{22}(OH)_2$ ☐$Mg_7Si_8O_{22}(OH)_2$ to ☐$Fe^{2+}{}_7Si_8O_{22}(OH)_2$ ☐$(Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$ ☐$Ca_2(Mg, Fe^{2+})_5 Si_8O_{22}(OH)_2$ ☐$Ca_2(Mg, Fe^{2+})_5 Si_8O_{22}(OH)_2$
Quartz	SiO_2
Sepiolite	$Mg_4(Si_6O_{15})(OH)_2 \cdot (H_2O)_6$
Forsterite (olivine; Mg-endmember)	Mg_2SiO_4
Enstatite (orthopyroxene; Mg-endmember)	$MgSiO_3$
Dolomite	$CaMg(CO_3)_2$
Calcite	$Ca(CO_3)$
Magnesite	$Mg(CO_3)$
Chlorite[b]	$Mg_5Al(AlSi_3O_{10})(OH)_8$

[a] *Amosite is the commercial term for amphibole asbestos principally composed of grunerite asbestos, but known to contain small amounts of anthophyllite and actinolite asbestos (see Zoltai (1981) and Wylie (2016) and references therein).*

[b] *Formula here is given for clinochlore, one of the most common members of the chlorite group; Fe^{2+} may substitute for Mg^{2+}, grading into the Fe-rich endmember, chamosite.*

3.1 Asbestos

Dorling and Zussman (1987) documented four major types of habit exhibited by amphibole minerals, which include "massive, prismatic, finely acicular, and asbestos." Prismatic and acicular habits are most common, and the asbestiform habit is very rare (Zoltai, 1979; Walker and Zoltai, 1979; Nesse, 1991; Klein, 1993; Veblen and Wylie, 1993). Amphiboles are estimated to compose ~2–5% of the Earth's crust (Nesbitt and Young, 1984), making them the fifth-most-abundant mineral. By area, 6–10% of the rock types exposed at the surface in the coterminous United States are amphibole-bearing (Wylie and Candela, 2015). Zoltai (1979) estimates that *less than 1% by volume of all amphiboles* may have crystallized with the asbestiform habit, and Wylie and Candela (2015) estimate that less than 0.1% of amphibole-bearing rock underlying the coterminous United States contain asbestos. The rarity of asbestos indicates that special conditions are required for its formation.[3]

[3] Asbestos is most typically found as veins in which fibers grew perpendicular to the host rock walls as "cross fibers" or (sub)parallel to them as "slip fibers" (Zoltai, 1981; Ross and Nolan, 2003; Evans, 2004). Veins, in general, are not

Indeed, amphibole asbestos and cleavage fragments are fundamentally different (Figure 4 [p. 8]). Structural differences internal to amphibole asbestos and non-asbestiform amphiboles include: 1) abundant twinning[4] in asbestos compared to non-asbestiform amphiboles, and 2) abundant subgrains and dislocations[5] in non-asbestiform amphiboles versus none in amphibole asbestos (Zoltai, 1981; Dorling and Zussman, 1987; Veblen and Wylie, 1993). Other key structural differences include the size, shape and surfaces of the grains themselves. When crushed, ground, etc. (communition), asbestos bundles break down into the individual fibrils (or smaller individual fibers), whereas non-asbestiform amphiboles tend to break along {110} cleavage planes. For this reason, the {110} plane is a common surface for (non-asbestiform) amphibole cleavage fragments (Figure 5 [p. 9]). In contrast, several authors have observed that amphibole asbestos fibrils commonly lie on surfaces that correspond to the {100} plane (Wylie, 1979, 2016; Dorling and Zussman, 1987; Brown and Gunter, 2003; Bandli and Gunter, 2014). In other words, amphibole cleavage fragments and amphibole asbestos, despite having the same mineral formula and same basic structure at the smallest scale, form in different ways and have different structural properties that control which crystallographic planes are typically exposed on their surfaces. In turn, because different crystallographic planes host specific elemental sites, which planes form mineral surfaces are significant factors in surface chemistry (Figure 5).

The differences described above influence particle size distributions observed for populations of mineral grains. Harper et al. (2008) demonstrated that width may be the most effective discriminator in size characterization studies of cleavage fragments versus asbestiform amphibole analogs. Fibril widths are typically less than 0.5 microns in diameter (Wylie and Candela, 2015; Wylie, 2016). Zoltai (1981) notes that if "fibers" are observed as single crystals (i.e., not associated with bundles) and have diameters larger than typical fibrils, they are capillary or filamentary crystals; strictly speaking, they are not asbestiform.

A key property of asbestos that made it commercially valuable is its high tensile strength and flexibility. This tensile strength is generally associated with low defect densities of fibril surfaces (Zoltai, 1981). Experiments have demonstrated that chemical resistance is a feature of the asbestiform habit, as explicitly noted in its definition, which is also attributed to the lower number of surface defects compared to non-asbestiform varieties (Walker and Zoltai, 1979; Gualtieri et al., 2018). Imperfections in the crystal structure due to deformation (i.e., dislocations or cleavage breaks) are known to be higher energy sites. Because the system wants to minimize its energy (see discussion of Gibbs free energy on p. 10), deformed regions of a crystal with structural imperfections are prone to faster dissolution rates (e.g., Schott et al., 1989; Lasaga and Lüttge, 2001). High densities of steps and kinks on mineral surfaces also show an effect of increasing dissolution rates (Arvidson et al., 2003). Steps and kinks are known to be common on growth

---

uncommon in nature but asbestos-bearing veins are. The minerals that crystallize in veins and their habits are ultimately controlled by the metamorphic and deformation environment (rock chemistries, pressure, temperature, fluid volume and chemistry, rock strength, stress field). Observations of asbestos crystal surfaces and morphology are consistent with laboratory experiments that indicate asbestos forms by rapid growth in a supersaturated fluid-filled medium (Dorling and Zussman, 1987). The implication is that asbestos nucleates on rock surfaces and grows in fluid fluid-filled fractures or other voids (Evans, 2004; Ross et al., 2008). This association of asbestos with voids, brittle faults, and fractures indicate that, in addition to fluid composition, low temperature and/or pressures conditions are important factors in its formation.

[4] Twinning refers to symmetrical intergrowths within a larger crystal, where mirror images effectively occur across certain planes in the crystal lattice. In amphibole asbestos, twinning occurs along the {100} crystallographic plane shown in Figure 5.

[5] Subgrains are domains within a crystal lattice that are slightly misoriented relative to neighboring domains. They are bound by dislocations, which are analogous to small faults or offsets in the crystal structure.

surfaces of prismatic or acicular amphiboles and their cleavage planes but are not commonly associated with their asbestiform counterparts (Dorling and Zussman, 1987). Furthermore, because cleavage fragments form due to rock deformation, either by tectonic processes or by crushing and grinding, they are likely to dissolve faster. As a result, amphibole asbestos is associated with more chemically resistant Fe-bearing surfaces that can catalyze reactions compared to non-asbestiform amphiboles.

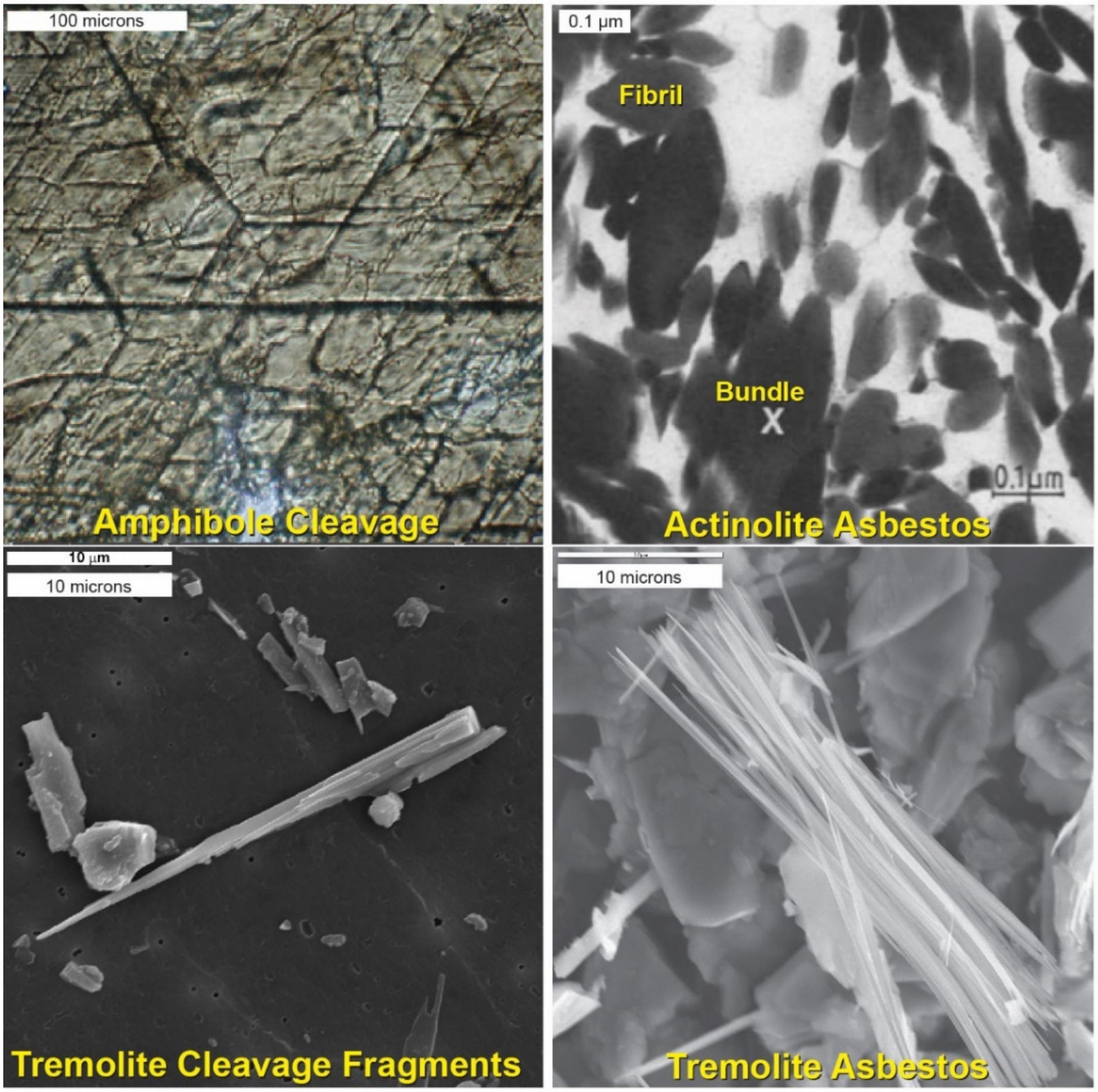
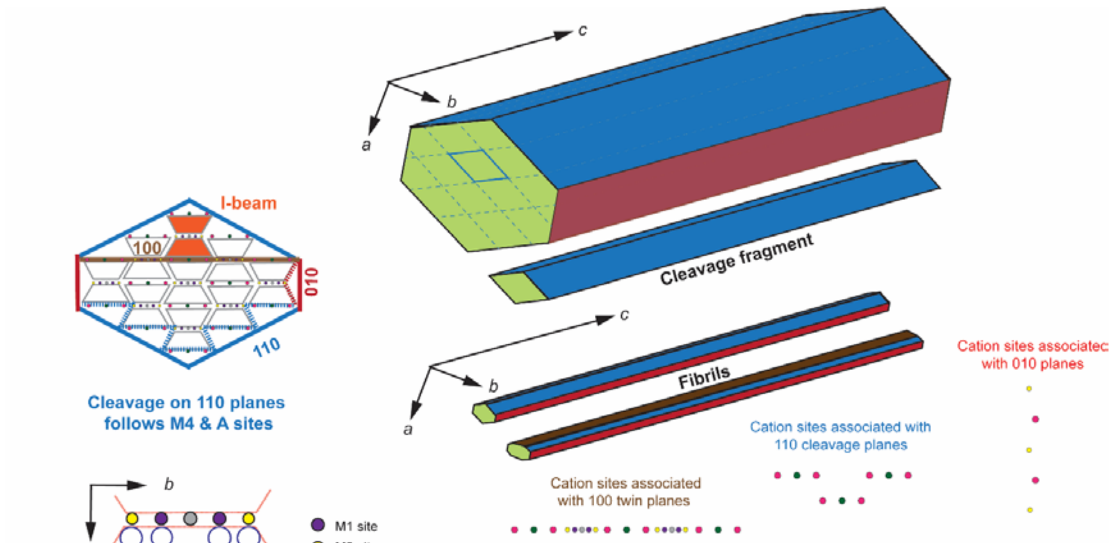


Figure 4. *Images comparing amphibole cleavage and cleavage fragments with amphibole asbestos. Upper images show basal cross-section views (i.e., a–b plane in Figure 5). Upper-left image shows well-developed {110} cleavage planes (appearing as dark lines bounding diamond-shaped crystal volumes) seen in polarized light microscopy. Image from: http://www.science.smith.edu/geosciences/petrology/petrography/hornblende/P1010004.jpg Upper-right electron micrograph from Dorling and Zussman (1987) shows fibrils and fiber bundles. Fibrils are typically less than 0.1 microns in width, whereas bundles (example denoted by authors with an "x") are larger clusters with more irregular outlines. Lower images show tremolite cleavage fragments and bundle(s) of tremolite asbestos fibrils taken with scanning electron microscopes (note similar scale of both images). Image on lower left is from https://usgsprobe.cr.usgs.gov/images/hexagonite.jpg; (hexagonite is a variety of tremolite). Image on lower right is from https://usgsprobe.cr.usgs.gov/images/asbestos_2.jpg.*



Exposed on	100	010, 100	100	110, 010, 100
Cation site	M1	M2	M3	M4
Anthophyllite	Mg	Mg, Fe^{3+}*	Mg	Mg, Fe^{2+}*
Grunerite (Amosite)	Fe	Fe, Mg*	Fe	Fe, Fe^{2+}*
Tremolite	Mg	Mg, Fe^{2+}*, Fe^{3+}*	Mg	Ca
Riebeckite (Crocidolite)	Fe, Fe^{2+}*	Fe, Fe^{3+}*	Fe, Fe^{2+}*	Na, Mg*
Actinolite	Fe, Mg	Fe, Mg, Fe^{3+}*	Fe, Mg	Ca

*Denotes preferred M site

Details re: Fe^{2+} and Fe^{3+} summarized from Pollastri et al. (2015, 2017)

Cations from Klein and Hurlburt (1993)

Figure 5. *Diagrams depict differences between cleavage fragments and asbestos fibrils in terms of crystallographic planes that form surfaces. I-beams represent the fundamental double-chain strands in amphiboles. Cation sites associated with each surface are shown, which depends on the type of amphibole. Details regarding Fe^{2+} and Fe^{3+} in table summarized from Pollastri et al. (2015, 2017), and cations from Klein and Hurlburt (1993).*

4.0 Formation of Talc Deposits: General principles of metamorphism and metasomatism

While talc is a common mineral in a variety of rocks, mineable cosmetic-grade[6] talc deposits are rare and require special conditions for formation. General principles of petrology—the study of the composition, occurrence and origin of rocks—are critical to understanding the formation process described below. For the non-geologist, baking provides a good analogy. That is, what comes out of the oven specifically depends upon: 1) the *composition* of ingredients that are mixed and in what ratios; 2) the *temperature* of the oven; 3) the *time* spent in the oven; and 4) the atmospheric *pressure* (i.e., at sea level vs. high elevation). The science of petrology, therefore, can be thought of as the study of rock recipes. In nature, as in the kitchen, recipes can be scaled and the availability of some ingredients (or another resource, such as time) will be a limiting the factor in the volume of desired products that can be made.

Metamorphism is a process in which changes in mineralogy occur when a rock is exposed to temperatures, pressures and/or fluids different from the conditions under which it formed. The concept of metamorphism is critical to understanding the formation of talc deposits and, in the case of the deposits used in Johnson's Baby Powder and Shower to Shower, why asbestos is not associated.

[6] Standards for cosmetic-grade talc include ≥ 90% mineralogical purity. (See Fiume et al., 2015).

When geologic conditions change, the atoms in a rock are reorganized into more stable configurations—mineral compositions, structures and assemblages—with a lower energy state. Metamorphism, by definition, involves solid-state chemical reactions that are dependent on the physical movement (diffusion) of chemical elements through a solid medium; fluids may or may not play a role and, generally, melt is absent except at very high temperatures (> 650 °C; 1202 °F). The laws of thermodynamics govern this process. Because metamorphism involves the diffusion of elements through solid crystal structures, lattice site by lattice site, or along grain boundaries, metamorphism typically occurs over geologic timescales (millions of years). High temperatures, the presence of fluids and deformation can enhance diffusion and thus recrystallization rates.

The term protolith refers to the original "parent rock," the bulk composition[7] of which has a primary control over the types and relative abundances of minerals that will comprise an equilibrium assemblage. An equilibrium assemblage is a combination of minerals that has the lowest possible Gibbs free energy[8] given the pressure, temperature and bulk composition of the system. As noted earlier, Gibbs free energy is also associated with structural defects in crystal structures and grain boundary geometries within the rock. The more defects and the more convoluted the geometries, the higher the energy of the system and the higher the driving force for recrystallization. For a given bulk composition, the equilibrium assemblage is a function of the pressure and temperature conditions of metamorphism, often described as metamorphic facies (see Figure 6 and examples in figure caption).

There are three main different types of metamorphism, and they are not mutually exclusive. Regional metamorphism generally occurs during mountain building processes, referred to orogenesis, such as when continents collide. Contact metamorphism occurs more locally, possibly during regional metamorphism, due to juxtaposition of a hot magmatic intrusion with colder wall rocks. Hydrothermal fluids, possibly associated with magmatic intrusions, can also be a driver of metamorphism due to local interactions between hot ion-rich fluids and the wall rocks with which they interact.

The results of metamorphism depend on open vs. closed system behavior. In a closed system, there is no change in the overall composition of the rock, only the rearrangement of atoms into new minerals occurs. The baking analogy is you can only use the ingredients you have on hand in the kitchen. In contrast, in an open system, chemical components may be added or lost by a rock during metamorphism (i.e., you can borrow a cup of sugar or eggs from your neighbor). The metamorphic process can make as much of whatever the conditions allow, until the conditions change, or one of the necessary elements runs out.

The formation of talc deposits is the result of metasomatism, a special case of open-system metamorphism in which the bulk composition of a rock changes due to interactions with fluids and/or the transfer of elements between neighboring rocks. For example: **Rock A + Fluid = Rock B** *-or-* **Rock A + Rock B = Rock C + Rock D + ...** The degree to which chemicals are exchanged across a rock-fluid or rock-rock boundary and the width of the alteration zone are strongly dependent on temperature, time, the presence of fluids and the intensity of chemical gradients. The process can be further enhanced by deformation.

[7] We can define the overall chemistry, or bulk composition, of a rock by major elements (> 2 wt. %), minor elements (2–0.1 wt. %) and trace elements (< 0.1 wt. %).

[8] At a specified pressure and temperature, Gibbs free energy (G) can be defined as $G = H - TS$, where H is enthalpy, S is entropy and T is temperature in degrees Kelvin.

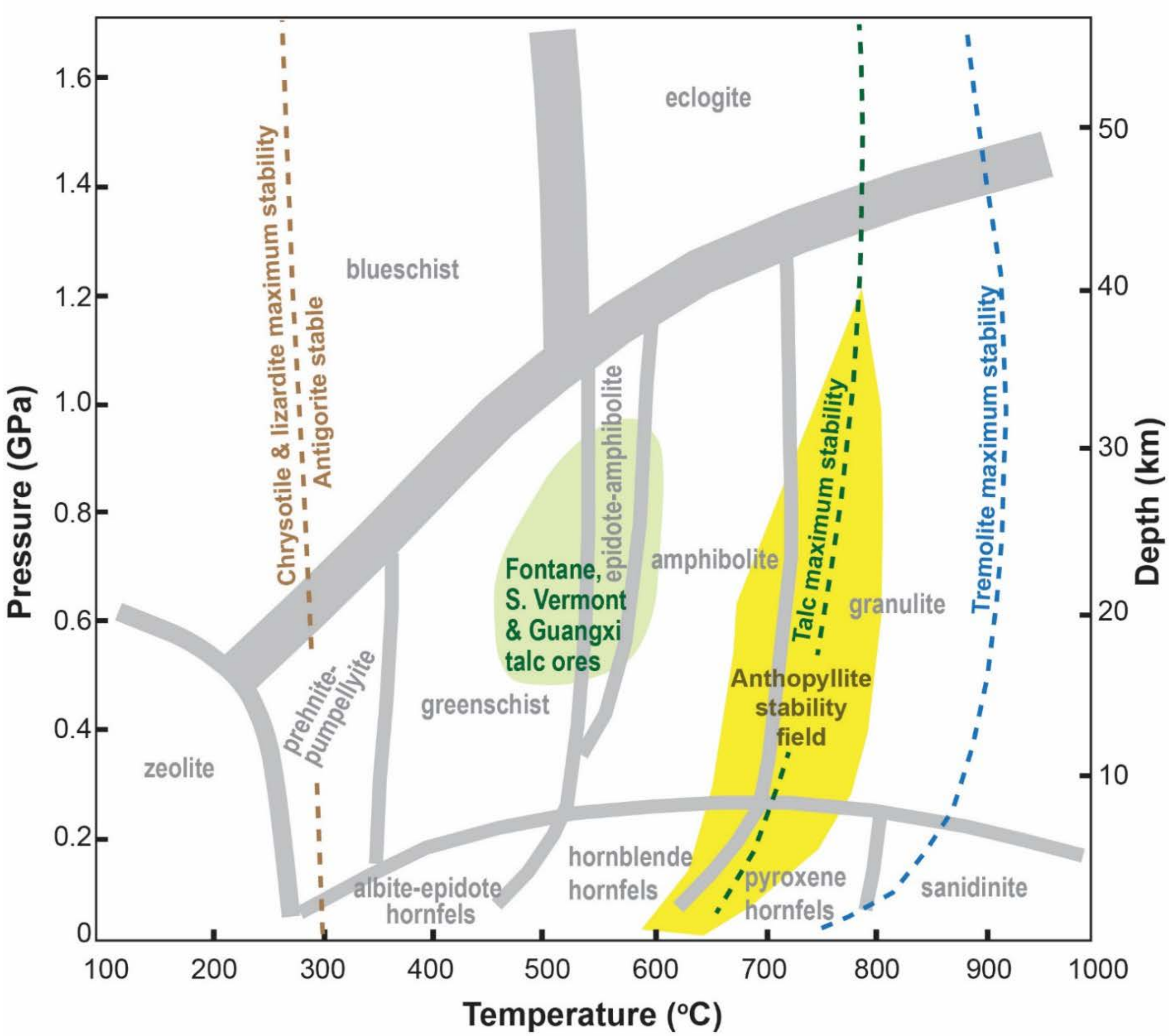


Figure 6. *Pressure-temperature diagram modified from Winter (2001) showing in gray the general boundaries of different* *metamorphic facies* *(e.g., greenschist facies) that represent conditions under which certain combinations of minerals (i.e., equilibrium assemblages) are stable as a function of a rock's bulk composition. The diagram is appropriate for water-saturated ultramafic rocks (CaO-MgO-SiO_2-H_2O). For example, burial of rocks during regional metamorphism is typically associated with greenschist–amphibolite-facies metamorphism. Greenschist-facies metamorphism of mafic rocks (e.g., basalt) will tend to result in a mineral assemblage including chlorite + albite + epidote + actinolite + quartz, whereas amphibolite-facies metamorphism of mafic rocks is typically associated with the assemblage hornblende + plagioclase + quartz. Mineral stability fields for the serpentine minerals taken from Evans (2004). Stability field of talc, tremolite and anthophyllite from Winter (2001); see also discussion in section 5.2. The green shaded field shows the general pressure and temperature conditions attending talc ore formation from which Johnson's Baby Powder and Shower to Shower were sourced, as described in the text. Guangxi talc ores formed at greenschist facies, southern Vermont and Fontane talc ores at up to lower amphibolite facies. Note that conditions favoring asbestos formation are generally associated with low-temperature and/or low-pressure conditions (zeolite, prehnite-pumpellyite and hornfels facies).*

4.1 A framework for analysis

By integrating observations made in the field and under the microscope with laboratory experiments, petrologists have constrained what minerals will form in a given rock type under different pressure and temperature conditions. Using this knowledge, we can either predict outcomes for different rock types (protoliths) and geologic histories or infer what the protolith and geologic history was based on observations of minerals and textures in rocks in the field and in petrographic thin sections.[9]

Figures 6 and 7 are examples of graphic representations petrologists employ to think about mineral assemblages and metamorphic reactions to constrain rock histories. For example, in Figure 6 above, the brown dashed line shows the stability fields of the different serpentine minerals as a function of pressure and temperature. Chrysotile and lizardite are stable (i.e., have the lowest Gibbs Free energy) at low temperatures, whereas antigorite is the most stable above ~300°C, depending on pressure. If we see chrysotile and lizardite veins in a serpentinite[10], we can infer that those veins formed at low-temperature conditions. Likewise, the green dashed line represents the maximum stability of talc, where it starts to undergo a metamorphic reaction to form anthophyllite + quartz + water. If in a thin section we see talc texturally associated with anthophyllite and quartz, we can infer that the rock records a frozen metamorphic reaction[11] that occurred at granulite-facies conditions, or temperatures ~700°C. This inference would be strengthened if we saw granulite-facies mineral assemblages in neighboring rock types.[12] The yellow field represents the stability field of anthophyllite in ultramafic bulk compositions. Its presence in a rock would testify to the rock having experienced upper-amphibolite or granulite facies conditions. If the maximum metamorphic grade recorded by a suite of rocks is lower amphibolite facies conditions (i.e., maximum temperature is less than ~650°C), ultramafic rocks in that suite of rocks would not contain anthophyllite; they would instead contain tremolite.

Figure 7 shows a chemographic projection, which is basically a graphical expression of the proportions of chemical components in rocks and the minerals that comprise them. To use a chemographic projection, we need to decide what our most important ingredients are. For carbonate and ultramafic rocks, the key chemical components are CaO, SiO_2, and MgO, and they are assigned to the three apices of the triangle. We need to consider fluids such as water (H_2O) and carbon dioxide (CO_2) and decide if they are abundantly available or are a limited resource. In the case of Figure 7 and the discussion that follows, the premise is that they are freely available to participate in reactions.

To plot a mineral or rock on the chemographic diagram, one must first determine the relative proportions of the chemical components. The mineral quartz (Qtz), SiO_2, plots at the SiO_2 apex. In this case, the mineral shares the same formula as the chemical component and 100% of the chemical composition of quartz is SiO_2. In the case of talc (Tlc), which has the formula $Mg_3Si_4O_{10}(OH)_2$, the chemical proportions are 3 MgO to 4 SiO_2 to 1 H_2O. Since water is ignored in the plotting scheme, we normalize the other chemical components to 100% and talc is plotted as 43% MgO and 57% SiO_2, therefore lying in that relative position

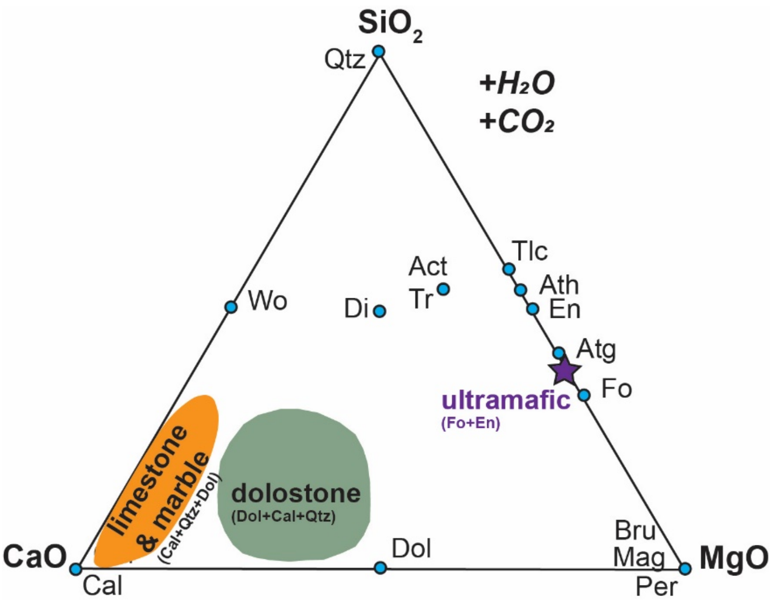
[9] A standard thin section is a polished 30-micron slice of a rock that can be examined using polarized light microscopy (petrographic microscope).

[10] Serpentinite is a rock predominantly composed of serpentine minerals.

[11] Metamorphic reactions can be preserved in rocks for a variety of reasons. For example, a chemical component might be limited ("runs out") or because of the timescales needed for reactions to go to completion, exceed the timescale of metamorphism.

[12] Petrology is effectively a forensic science, and for this reason petrologists work with suites of rocks rather than a single specimen.

on the line connecting the MgO and SiO_2 apices. The mineral tremolite (Tr), $Ca_2Mg_5Si_8O_{22}(OH)_2$, has the relative proportions (ignoring water) of 2 CaO to 5 MgO to 8 SiO_2, or 13.3% CaO, 33.3% MgO, and 53.3% SiO_2. Therefore, tremolite plotted based on these proportions lies closest to the SiO_2 apex, next closest to the MgO apex, and farthest from the CaO apex.



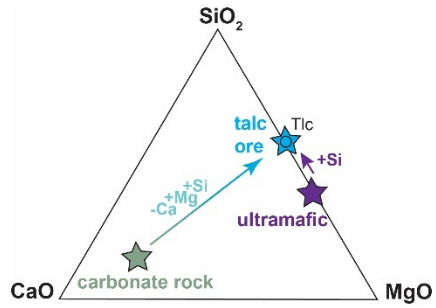


Figure 7. *Chemographic diagrams for the CaO-SiO2-MgO chemical system for calcareous and ultramafic rocks modified from Winter (2001). Plot on left-hand side shows where rocks and minerals plot based on their chemical composition. Because of solid solution (e.g., the ability for Fe to replace Mg in a crystal structure), mineral positions may vary slightly due to actual mineral composition. Here, actinolite plots with tremolite because this simplified plotting scheme does not account for Fe. Abbreviations are as follows: Qtz = quartz, Act = actinolite, Tr = tremolite, Sep = sepiolite, Tlc = talc, Ath = anthophyllite, En = enstatite, Atg = antigorite, Fo = Forsterite, Bru = brucite, Mag = magnesite, Per = periclase, Dol = dolomite, Cal = calcite, Wo = Wollastonite and Di = diopside. Diagram in upper-right illustrates examples of changes in bulk composition due to metasomatism (open system metamorphism) resulting in the formation of high-purity talc deposits. See section 4.1 for discussion.*

One can plot rocks on a chemographic diagram based on their bulk composition as well as the combinations of minerals resulting from metamorphic processes. The mineralogy of the rock, including the relative proportions of minerals, must obey the rules of mass balance. That is, the relative proportions of the minerals must be consistent with the bulk composition. For example, the purple star shows a typical bulk composition of an ultramafic rock, an Mg-rich rock derived from Earth's mantle, that is composed of the minerals forsterite (Fo) and enstatite (En) (Table 2). During metamorphism, if the system is closed, no change in bulk composition occurs because no chemical components are added or lost from the system—that is except for water, which is freely available in this case. Metamorphism of ultramafic rocks in the presence of water at temperatures below ~500°C (~932°F) results in the formation of serpentine minerals[13], typically antigorite or lizardite depending on the temperature and pressure of metamorphism (Figure 6). Note that the mineral antigorite (Atg) plots very close to the purple star, as would lizardite. Based on the starting bulk composition, metamorphism in the presence of water would transform the ultramafic rock almost completely to antigorite at greenschist-facies conditions (~350–500°C; Figure 6), but there would have to be a little residual forsterite left in the rock because the bulk composition is richer in MgO than the mineral formula for antigorite (i.e., the excess MgO is manifest in preservation of some

[13] This transformation of ultramafic rocks into a serpentine-dominated mineralogy is called serpentinization.

of the original olivine). Because calcium is an essential chemical component in the tremolite, we would not predict any tremolite to form during metamorphism given the bulk composition of the ultramafic rock as defined in this example.

In the case of an open system, where chemicals other than H_20 or CO_2 may be added or lost due to chemical exchange between rock units or the introduction of silica-rich fluids via shear zones, faults or fractures, a talc deposit may form. For this to occur, a significant amount of SiO_2 must be added to the ultramafic rock system, ultimately shifting the bulk composition of the rock represented by the purple star to the position of talc (Tlc) on the graph (Figure 7). Likewise, in the case of a carbonate-rich (Cal ± Dol) protolith, SiO_2 and MgO must be added to the system to make a high-purity talc deposit.

The above principles highlight the fact that, while talc is a common metamorphic mineral in metamorphosed ultramafic and carbonate rocks, mineable high-purity talc deposits are the result of rare instances of rather extreme metasomatism, in which the bulk composition of a protolith is changed to something effectively matching (or very close to) the talc mineral composition.

5.0 Evaluation of talc mines used in Johnson's Baby Powder and Shower to Shower

Because each talc deposit is unique, an overview of the formation of talc deposits mined for use in Johnson's Baby Powder and Shower to Shower follows for the Fontane (Italy), southern Vermont and Guangxi (China) mines.

5.1 Sources of data

For the summaries and opinions provided below, I relied on peer-reviewed, published scientific literature and the examination of *primary sources* of data and observations. I emphasize the latter because, as discussed below (e.g., Section 5.3), there has been a lot of misinformation. Articles relating to the specific mines from which talcum powders were derived are somewhat sparse. In all cases, I integrated regional studies to understand the broader context and metamorphic conditions associated with the formation of the talc deposits. My examination of reports outside of the peer reviewed literature was very limited. For Guangxi talc ores, I used company documents (e.g., IMERYS413792) to find descriptions of geologic formation names and locations, and then used that information to search the peer-reviewed literature for relevant articles. This also facilitated assessing consistency between company reports and published findings.

In the case of both the southern Vermont talc mines and Fontane talc mines in Italy, I examined reports by Dr. Pooley[14] from the Department of Mineral Exploration at University College Cardiff in Wales. In my professional opinion, Dr. Pooley's reports are important records of data and observations that augment and are consistent with the published literature. Dr. Pooley sampled not only the talc ores, but representative samples of rock types included in and adjacent to the ore bodies. This sampling strategy is consistent with that required to understand the talc ores in the context of a geologic system and assess the potential for asbestos contamination. Based on my expertise, I focused on his petrographic thin section observations (polarized light microscopy) from which one can identify major, minor, and accessory minerals, their habits and their textural relationships (e.g., intergrowths, replacement textures, deformation at the microscale). I found his electron microscopy and X-ray diffraction data results to be consistent with the petrographic descriptions and photomicrographs.

[14] The report titles include: *Talc Product Safety and Purity Project: 1. Talc Ore Sampling – Fontane Mine – Italy; Report of Italian Mine Samples J & J.; Report of the Examination of Rock Samples from the Vermont Mine.*

The summaries provided below emphasize findings from the published literature, noting consistency between the published data and that in the industry reports examined.

5.2 Talc from the Fontane talc mines, Val Germanasca, Italy

The Fontane Talc Mine workings are in Val Germanasca in the Pinerolo district of the Torino province of Italy. Cadoppi et al. (2016), Sandrone et al. (1990) and Sandrone and Zucchetti (1988) indicate that the Fontane talc bodies are embedded within a pre-Carboniferous (i.e., older than ~355 million years) polymetamorphic complex of the Dora Maira Massif (southern blue map unit in Figure 8). The talc ores are associated with layers of schist, marble, and gneiss (Del Greco and Pelizza, 1984; Cadoppi et al., 2016), corresponding to metamorphosed mudstone, limestone and basalt, respectively. The talc ore bodies are of high purity and confined to a sheet-like body with local impurities that include lenses of carbonate or schist of varying size (Del Greco and Pelizza, 1984; Sandrone and Zucchetti, 1988). Cadoppi et al. (2016) report that the processes leading to Fontane Talc mineralization are still debated. The talc formation is hypothesized by some to have resulted from regional metamorphism of an Mg-rich clay horizon such as sepiolite (Table 2; Figure 7) (Sandrone and Zucchetti, 1988). However, juxtaposition of carbonate rocks, schists, and metabasalts (the prefix "meta" means metamorphosed) as layers that host the talc ores, and the inclusion of these rock types locally within the talc ores, are consistent with a metasomatic origin (i.e., metasomatism of a carbonate rock to a talc ore; Figure 7).

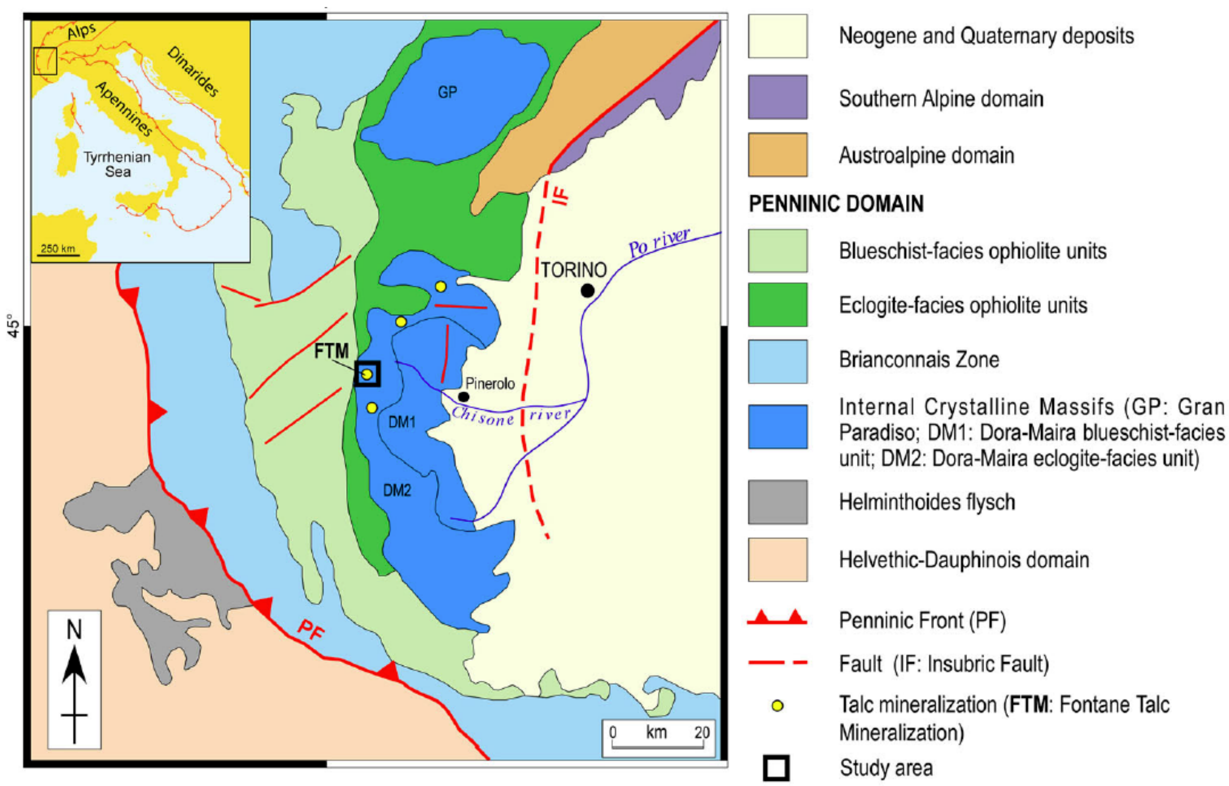


Figure 8. *Map showing location of the Fontane talc mineralization (yellow dots) from Cadoppi et al. (2016). The Fontane talc mines (FTM) are hosted within the old, poly-metamorphosed continental crust of the Dora Maira unit. Note that this suite of rocks (blue) are in a different geologic unit than the ophiolite (oceanic crust and mantle) units (light and dark green), where asbestos has been documented. The tectonic juxtaposition of these map units post-dates the formation of the talc (see discussion in text).*

The high-purity Fontane talc deposits formed early in the geologic history of the rocks and have been geologically stable since their formation. Integrated studies of metamorphism and deformation recorded by the talc ores and their host rocks indicate a complex polymetamorphic history in which the talc ores formed prior to the Cenozoic Alpine orogeny (i.e., the talc formed greater than ~60–35 million years ago) (Gasco et al., 2011; Cadoppi et al., 2016). Gasco et al. (2011) demonstrate that the rocks hosting the Fontane talc deposits, and thus the talc deposits themselves, never exceeded temperatures of ~575°C during the Alpine phases of metamorphism. This is important because studies have shown that talc, once formed, is stable up to at least 650°C (1202°F) and as high as 800°C (1472°F) depending on pressure (e.g., Pawley and Wood, 1995; see also Sandrone and Zucchetti, 1988, and references therein; Figure 6).

The formation and location of asbestos and talc in the western Alps are clearly separated in both space and time. Asbestos is well-documented in ophiolite (sections of oceanic crust and upper mantle, mainly mafic and ultramafic rocks) units in the Piemonte zone (Labagnara et al., 2013). However, the talc ore bodies have no relationship to the ophiolites nor any direct geologic contact with them. The juxtaposition of the ophiolites (green units) and the Dora Maira massif (blue unit) that hosts the talc ores is the result of the Alpine orogeny, which postdates the formation of the talc ores by hundreds of millions of years. While tremolite[15] is documented in the literature in some rock types adjacent to talc ores, and occasionally found in rock fragments included within the talc ore bodies (Sandrone and Zucchetti, 1988; Cadoppi et al. 2016), there are no reports of asbestos associated with rock units in the Fontane talc mines in the published, peer-reviewed literature (nor detections of it in tests of Fontane mine-derived talcum powders; e.g., Marconi and Verdel, 1990).

The minerals and textures reported by Dr. Pooley for samples of the Italian mines are consistent with the geologic data and metamorphic histories documented by the publications cited above. Dr. Pooley examined more than 40 rock samples from a variety of rock types adjacent to the talc ores, as well as the talc ores themselves and specimens discarded during the screening stage. No asbestos or asbestiform minerals are reported. The only amphibole(s) observed are non-asbestiform calcic amphiboles, principally tremolite. The tremolite documented is prismatic, coarse-grained and bladed, occurring in surrounding rock types (his samples I19, I32, I35), which are locally found as rock inclusions in ore bodies. Only one talc ore sample revealed tremolite found as long prismatic inclusions in garnet (sample I41). (See JNJTALC000165964; JNJTALC000347819).

In summary, the Fontane talc mines are hosted within a metamorphosed suite of crustal rocks including mudstone, carbonate and basalt protoliths. Based on the rock-type associations, the talc ores formed from metasomatism of carbonate rocks juxtaposed with Si-rich metasedimentary and Mg-rich metabasalts (in the presence of H_2O and CO_2) at temperatures up to ~575°C. In contrast to plaintiffs' experts' claims, there is no record of asbestos having formed in these rocks; the geologic conditions were unfavorable. Rather, the occurrence of asbestos in the region is associated with unrelated and spatially distinct ophiolite units.

5.3 Talc from southern Vermont, USA

The Vermont talc mines used for Johnson's Baby Powder and Shower to Shower are near Ludlow, Vermont (Figure 9). These talc deposits formed via metasomatism during the Acadian orogeny (Late Devonian, ~380–360 million years ago) at the interface between Mg-rich ultramafic (mantle derived) rocks juxtaposed with Si-rich metasedimentary rocks (Chidester et al., 1951; Cady et al., 1963; Sanford, 1982;

[15] Non-asbestiform tremolite.

Robinson et al., 2006). This metasomatic process is like that described in section 4.1 (i.e., metasomatism of ultramafic rock to talc). The age of the deposits was originally deduced from correlation of the foliations(s) exhibited by the talc deposit with those documented regionally, resulting from deformation during the Acadian orogeny.

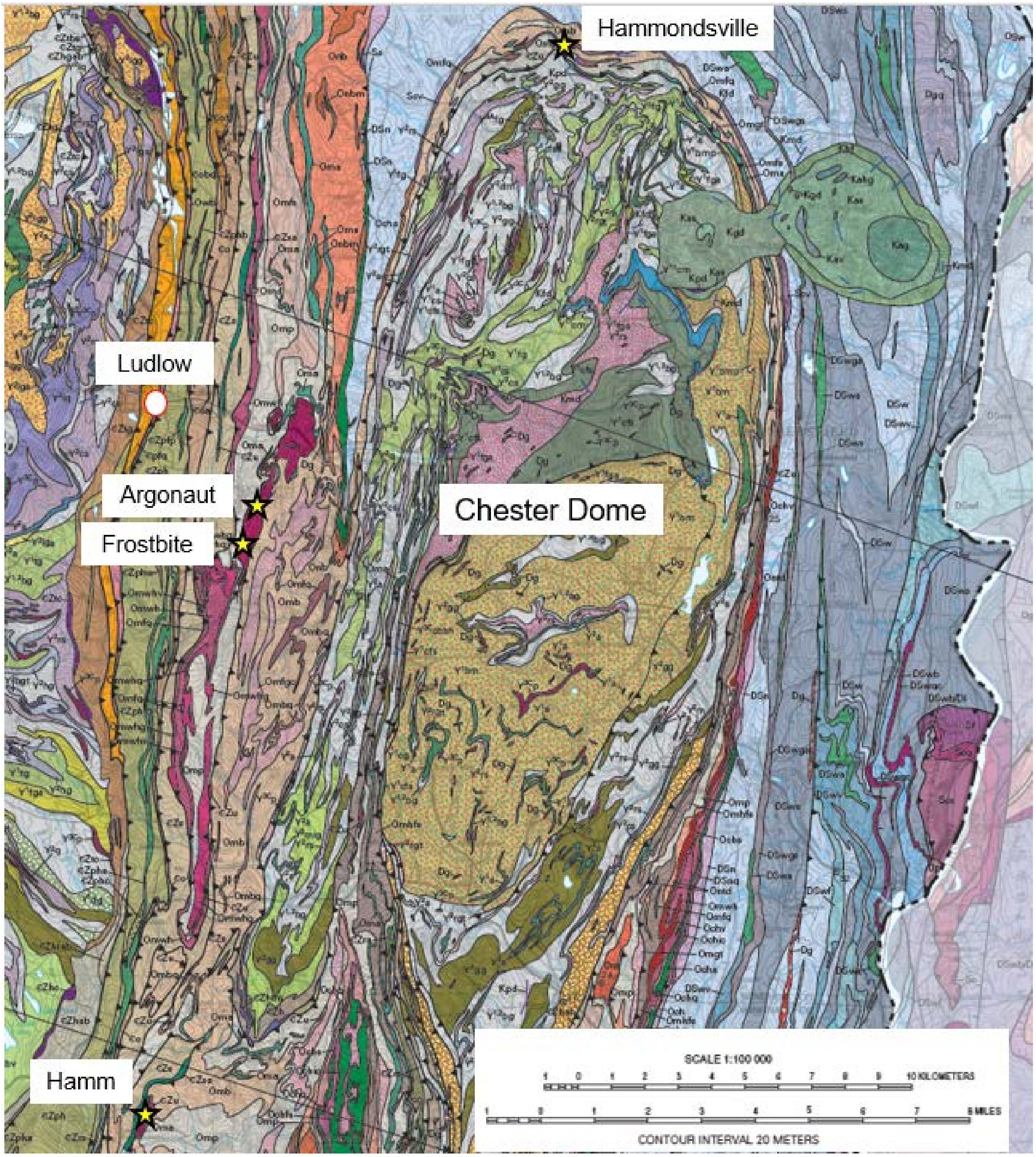


Figure 9. *Location of talc mines in the Ludlow region of southern Vermont. Talc for Johnson's Baby Powder and Shower to Shower came from the Hammondsville, Hamm and Argonaut mines. The Frostbite mine is also discussed in the text. The mines are associated with ultramafic rock units distributed within the Moretown Formation along the northern and western edges of the Chester Dome. Bedrock Geologic Map of Vermont from Ratcliffe et al. (2011). The complete version of this map, including the detailed index of rock units and map symbols, can be found here: https://dec.vermont.gov/geological-survey/publication-gis/VTrock.*

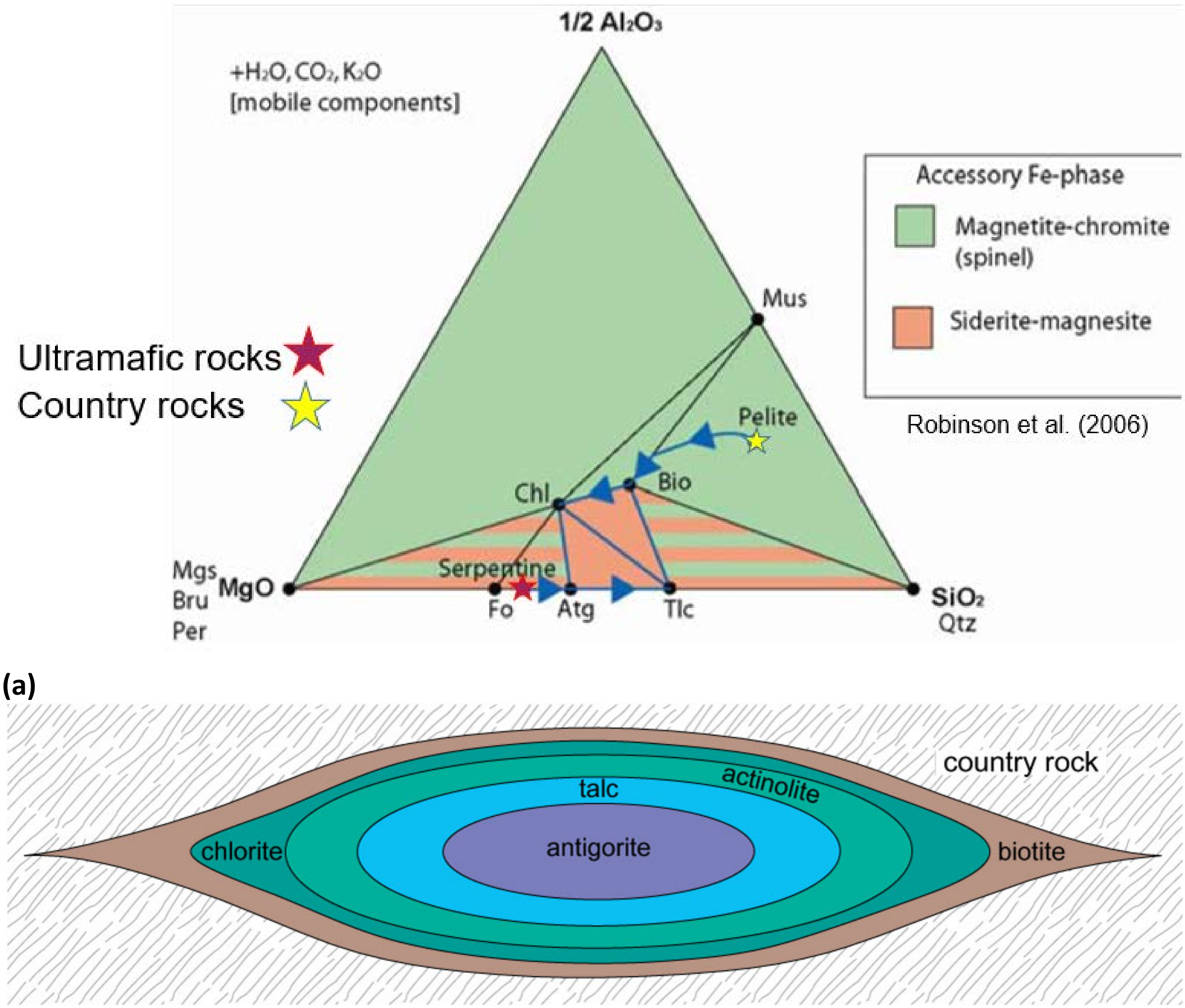
The most authoritative publication on the petrologic processes that control the formation of talc deposits associated with ultramafic bodies in southern Vermont is Sanford (1982). While Sanford (1982) did not study the Ludlow area deposits specifically, his case studies from Vermont and Massachusetts provide excellent context. Considered a classic, this work provides the basis for metamorphic petrology textbook discussions of the formation of talc deposits via metasomatism (e.g., Winter, 2001). Sanford's (1982) description of the Newfane quarry is an analog for the mines that produced cosmetic-grade talc based on the similarity in metamorphic conditions. Figures 10 and 11 show a chemographic diagram for the Frostbite mine in the Ludlow area as well as schematic representations of the mineralogical zonation resulting from metasomatism along the contact between an ultramafic body and metasedimentary country rocks. The diagram shown in Figure 11 is based on the Newfane quarry, located ~23 km (~14 mi) south of the Hamm mine and positioned similarly along the margin of the Chester dome. Depending on the bulk composition of the rock and the metamorphic grade, the amphiboles of note in rocks immediately adjacent to the talc ore are either actinolite or tremolite, with anthophyllite present only at the highest metamorphic grades (Sanford, 1982). More specifically, anthophyllite is predicted to form at $T \geq 650°C$ (1202°F; Figure 6), or upper amphibolite-facies conditions (Johannes, 1968). Such conditions are known to have been experienced in the core of the Chester Dome. Positioned along the flanks of the dome, the Hammondsville, Hamm and Argonaut Mines experienced *maximum* metamorphic conditions up to lower amphibolite-facies ($T \leq 600°C$, or 1112°F) conditions based on the mapping of isograds[16] in Doll et al. (1961) and Karabinos et al. (2010); therefore, amphiboles in the suite of rocks present at these mines are most likely either tremolite or actinolite, depending on the bulk composition (actinolite in more Fe-rich bulk compositions).[17] The Hammondsville mine is documented by Gillson (1927) and Chidester et al. (1951). These authors noted coarse flaky talc, a lack of serpentinite, and only localized masses of actinolite, which would be derived from blackwall, or the margin of the silica-rich metasedimentary rocks juxtaposed with the ultramafic bodies (i.e., the edges of the mineable talc deposit).

As noted previously, Dr. Pooley sampled a variety of representative rock types in the southern Vermont mine. Data and observations presented in Dr. Pooley's report for the southern Vermont talc mine are consistent with Sanford's (1982) findings for the talc zone formation in rocks of the Newfane quarry, which experienced similar metamorphic pressures and temperatures as the Ludlow area mines. Pooley documented no asbestos and found actinolite present only locally (sample V9) at margins of the talc bodies. The actinolite shown in Pooley's photomicrograph is coarse-grained and prismatic, not asbestiform. The suite of minerals observed in the country rocks is consistent with those described above and shown in Figure 11. Dr. Pooley's data are also generally consistent with the findings of Robinson et al. (2006) for the Frostbite Mine—although the latter does not report any amphiboles.

[Figure 10 on next page]

[16] Isograds are contours of equal metamorphic grade (i.e., demarcations of rocks that record similar pressures and temperatures of metamorphism based on their mineral assemblages).

[17] Note that other biopyriboles (Thompson, 1978; Bozhilov, 2013) have been documented as a function of bulk composition and metamorphic history. For example, at the Newfane locality, the thin epidote zone on the margins of the talc deposit shown in Figure 11 is known to contain intergrowths of hornblende, cummingtonite, and biotite interpreted to represent frozen metamorphic reactions (Sanford, 1982).



(a)

(b)

Figure 10. a.) *Chemographic diagram for the Frostbite Mine modified from Robinson et al. (2006). The diagram illustrates the chemical exchange between Mg-rich ultramafic rock and the Si-rich metasedimentary country rocks that resulted in the formation of talc deposits and accounts for a slightly different chemical system than that in Figure 7. Migration of SiO_2 from the country rocks (pelite, or mudstone, is the sedimentary protolith) into the partially serpentinized ultramafic body moved its bulk composition towards talc to form the talc deposit. Migration of MgO from the ultramafic body into the country rocks moved that bulk composition towards chlorite to form the chlorite-rich blackwall zone. These metasomatic reactions created mineralogical zoning schematically shown in b.* ***b.)*** *Schematic diagram from Winter (2001) showing the idealized mineral zonation resulting from metasomatic reactions between ultramafic pods or lenses and metapelites during regional metamorphism.*

[Figure 11 on next page]

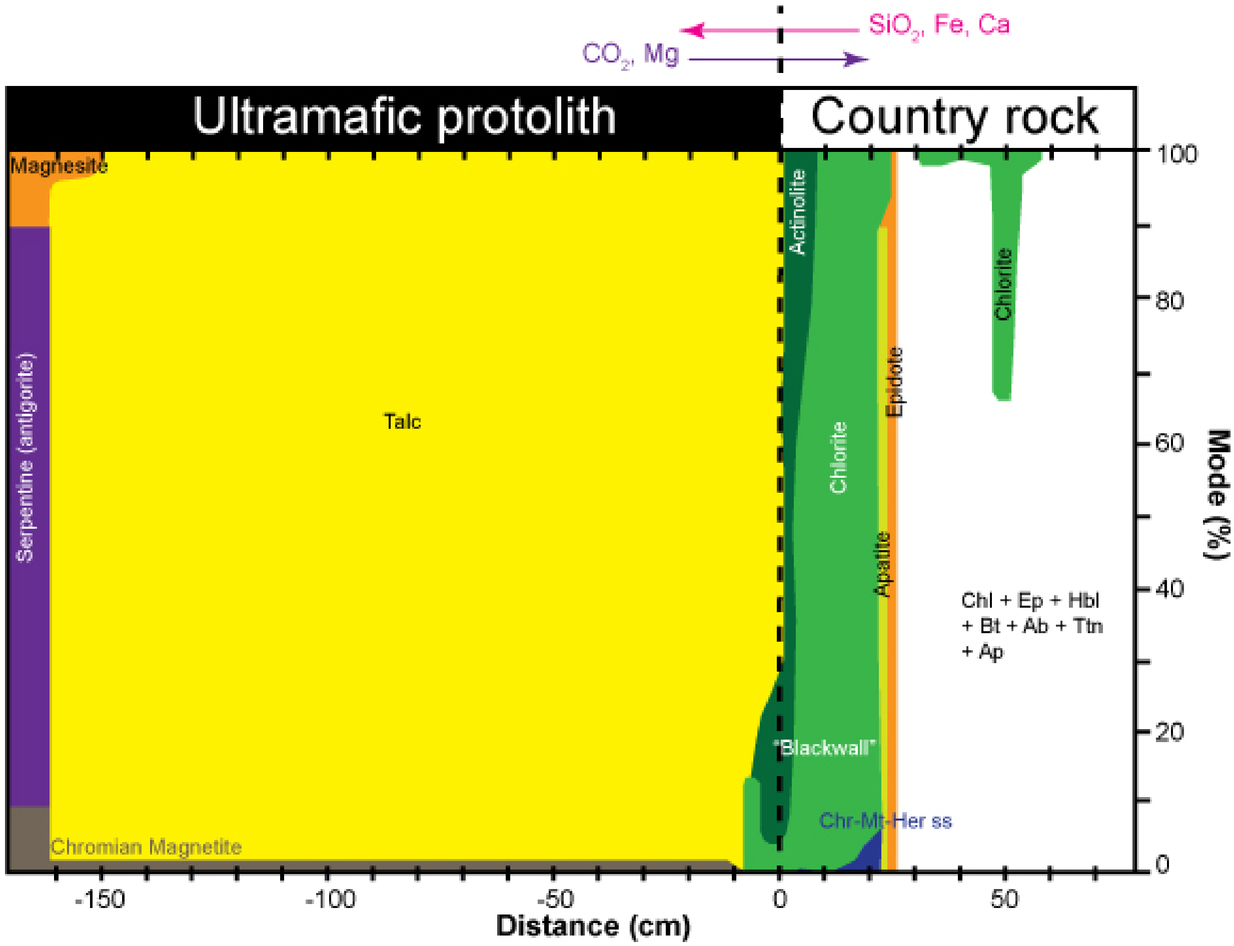


Figure 11. *Diagram depicting mineralogical zonation resulting from metasomatism of an ultramafic body in contact with metasedimentary rocks. The X axis is distance measured in outcrop and the Y axis is modal percent, or the relative proportion of each mineral depicted or listed in the graph. The original contact between the ultramafic rocks and the metasedimentary rocks corresponds to 0 cm along the X axis; negative distance is associated with distance into the ultramafic body and positive distance is into the country rocks. Chemical fluxes (i.e., diffusion of Si into ultramafic body from the country rock), due to strong compositional differences between the rock types, are shown by the arrows at the top of the figure. The redistribution of chemicals and the recrystallization of the rocks results in the formation of distinct mineralogical zones during regional metamorphism. The diagram depicts the blackwall zone, which is the chlorite-rich zone (± actinolite) on the country rock-side of the lithologic contact. "Chr-Mt-Her ss" is chromite-magnetite-hercynite solid solution; "Chl + Ep + Hbl + Bt + Ab + Ttn + Ap" is the general country rock mineral assemblage of chlorite + epidote + hornblende + biotite + albite + titanite+ apatite, which is indicative of epidote-amphibole-facies metamorphism.*

Regional studies are clear that asbestos formation in Vermont occurred during a different tectonic cycle and under different metamorphic conditions than talc ore formation (~60 to 100 million years prior). Hess (1933) studied the occurrence of chrysotile asbestos in ~150 ultramafic bodies in the Appalachians from Alabama to Newfoundland, including those in Vermont, noting that in the bodies associated with talc deposits 1) serpentinization always preceded steatization[18] and 2) that the chrysotile veins were

[18] Steatization is a term used in the literature for the formation of talc-carbonate rocks from metasomatism, with the talc-carbonate rock sometimes being referred to as steatite or soapstone.

associated with the older serpentinization event and were limited spatially to the ultramafic body (i.e., were never found in the country rocks). Similar conclusions were made by Chidester et al. (1951), a study specific to Vermont talc, as well as Chidester et al. (1978). The latter study was specifically focused on the asbestos-bearing rocks around Belvidere Mountain in the northern Vermont talc belt. More recent work by Honsberger and Laird (2018) modeled the metamorphic histories of the Stockbridge and Belvidere ultramafic bodies and concluded there were two distinct events: 1) an earlier phase of metamorphism during which serpentinization occurred in the presence of H_2O (with chrysotile asbestos forming locally in the latter stages of this event); and 2) a later event associated with steatization in the presence of H_2O and CO_2-bearing fluids. In other words, all publications are consistent that talc ore formation was unrelated to the formation of asbestos and occurred under different metamorphic conditions.

There are limited publications implying that asbestos is commonly associated with the ultramafic rocks in the southern Vermont talc belt (Van Gosen et al., 2006). I have reviewed these papers and detail my professional opinion and findings below.

Van Gosen (2006) summarized reported asbestos deposits in the northeastern United States. Of the 22 localities listed in Vermont, the reports are mainly of chrysotile, with amphibole asbestos being much more limited. In southern Vermont, there are five reported asbestos localities, none of which were mined for talc for Johnson's Baby Powder and Shower to Shower, that can be considered generally in the vicinity of the Ludlow area mines:

1) The Five Corners Mine is located ~11 km (~7 mi) WNW of the nearest cosmetic-grade talc deposit at the Hammondsville Mine. There, tremolite asbestos is stated to occur in ultramafic rocks hosted in the Ottauquechee Formation based on Perry (1929). However, the report of asbestiform tremolite in Perry (1929) is tenuous because the description of the minerals is not consistent with the definition of asbestiform in Table 1. I found a brief reference to chrysotile in the Five Corners Mine in Chang et al. (1965), but this was not included in the Van Gosen (2006) summary; nor have I found any citations that corroborate this finding. I also note the country rocks that host the ultramafic rocks at the Five Corners Mine are a distinctly different geologic formation than those hosting the cosmetic-grade deposits used in Johnson's Baby Powder and Shower to Shower, which are hosted in the Moretown Formation (i.e., they are a different belt of rocks with a different tectonic history).

2) The Bridgewater Hill occurrence is cited as reported in Perry (1929). It is ~19 km (~12 mi) NW of the Hammondsville Mine. Perry (1929) only states that "asbestos" was found as a loose piece of rock in a pasture, but the specific mineralogy and/or context of its geologic occurence is unknown. The country rock at this location is the Ottaquechee Formation, similar to that above for the Five Corners Mine.

3) Van Gosen (2006) notes a chrysotile occurrence in the Ludlow area, approximately ~2.4 km (~1.5 mi) NE of the Argonaut Mine, citing Chidester and Shride (1962) as cited in Van Gosen (2006). However, Chidester and Shride (1962) present no primary data or observations, and only cite Chidester et al. (1951) as their source. At issue here is the fact that Chidester et al. (1951) do not report any location information for their general report, making this reported locality impossible to evaluate.

4) Van Gosen (2006) indicates chrysotile is found in association with the Dover ultramafic body, which is ~27 km (~17 mi) SSE of the Hamm Mine. However, this occurrence is attributed to Chidester et al. (1951) and Chidester and Shride (1962). As noted above, the latter cites the former as its source of information and, once again, there is no documentation of asbestos in the Dover ultramafic body in Chidester et al. (1951).

5) The Chester Talc Mine, or Carlton Quarry, is listed in Van Gosen (2006) as an anthophyllite asbestos and possibly actinolite asbestos locality. The quarry is located ~10 km (~6 mi) NNE of the Hamm Mine and ~11 km (~7 mi) SSE of the Argonaut Mine. Again, Chidester et al. (1951) is cited as a source by Van Gosen (2006) but does not report asbestos at any specific locality. Another cited source, Gillson (1927), describes talc quarried here as low grade and suitable for some industrial purposes only. Two types of talc are noted: coarse flakes and fibrous pseudomorphs of actinolite; no asbestos is reported. Phillips and Hess (1936) describes needles of actinolite (i.e., acicular actinolite), some pseudomorphed by talc, but no asbestos. The occurrence of anthophyllite is summarized in Veblen and Burnham (1978). These authors describe complex intergrowths in the blackwall zone on the margin of the talc deposit where anthophyllite is replaced by intergrowths of chesterite, jimthompsonite, clinojimthompsonite and talc. Thus, the amphibole asbestos reported in Van Gosen (2006) is more consistent with '"transitional" phases' of Kelse and Thompson (1989) rather than amphibole asbestos. The predominance of anthophyllite at this locality is consistent with the location's position relative to mapped isograds (Doll et al., 1961; Karabinos et al., 2010), placing it at a higher metamorphic grade (higher temperature) than the cosmetic-grade deposits historically used in Johnson's Baby Powder and Shower to Shower.

In short, the sources cited by Van Gosen (2006) as documenting asbestos occurrences in southern Vemont do not actually report asbestos at any specific locality, are based on ambiguous terminology and/or are inconsistent with other reports and publications. As noted in Bain (1942), while talc associated with ultramafic bodies in Vermont is common, only about a third of these occurences are associated with "some fibrous magnesian mineral." In other words, asbestos may occur locally, but is not ubiquitous to talc-bearing ultramafic rocks.

Plaintiffs also rely on the Blount (1991) paper, but that is problematic in several ways. The data upon which the conclusions are based are not presented, only interpretations. This would/should preclude publication in any reputable scientific journal because there is no way to evaluate or reanalyze the data, such as employing other plotting methods that have been determined to be more meaningful discriminators of asbetos versus cleavage fragments when looking at large populations of data (e.g., Wylie, 2016; Chatfield, 2018). Additionally, the methodology implied in Blount (1991) indicates Dr. Blount only counted particles with aspect ratios ≥ 3:1 (as opposed to what is implied in Figure 6 from Blount (1991) for 'Talc I'), whereas the frequency diagrams in Campbell (1977) include aspect ratios < 3:1. This effectively renders the comparison of the datasets incorrect, as it would impact binning intervals thus the frequency distributions. Furthermore, it is not clear how the "tremolite" particle in Blount (1991) Figure 5, presumably representing tremolite asbestos from Sample I, was determined to be tremolite. At a minimum, the refractive index used (1.584) would not distinguish tremolite from other amphiboles present (Crane, 1992) or other trace minerals with appropriate densities that could have been concentrated by Blount's heavy liquid separation method. And finally, even Dr. Blount has questioned whether Sample I actually even came from Vermont.[19]

Overall, there are no data or observations, nor any petrologic argument, to support any claim of asbestos in the talc ores used in Johnson's Baby Powder and Shower to Shower from southern Vermont. The plaintiffs' experts' reports fail to make the distinctions between some talc formed during serpentinization driven by hydration of the ultramafic rocks, in which chrysotile formed locally under low-temperature (< 300°C) conditions, and talc ores that formed much later via metasomatism (in the presence of H_2O *and* CO_2) at medium pressure and higher temperatures (~500–600°C). They also accept at face value

[19] Deposition of Alice M. Blount, Ph.D. in Gail Lucille Ingham and Robert Ingham, et al., v. Johnson & Johnson, et al., April 13, 2018, 52:9–53:21.

generalizations about the association of talc and amphibole asbestos made by Van Gosen et al. (2004) that are not representative of the talc ores mined for Johnson's Baby Powder and Shower to Shower, and fail to understand the details of the local and regional geology. The latter is apparent from 1) their assumption that all ultramafic rock bodies in Vermont have the same origin and similar history and 2) failure to recognize the complex distribution of rocks of differnet metamorphic grade resulting from multiple tectonic events.

5.4 Talc from the Guangxi Province in China

Little information is available in the peer-reviewed published literature on the talc deposits in the Guangxi Province in China. The geology of the Longsheng County talc mines of interest (Jizhua, Tongzishan, Guping and Shanglang mines) is deduced from Li (1979), Yao et al. (2016) and Zhao et al. (2018). The talc deposits are hosted in dolomitic marbles of the Hetong Formation in the Danzhou Group (Figure 12), which also includes metamorphosed sandstones and mudstones intercalated and intruded by mafic igneous rocks.

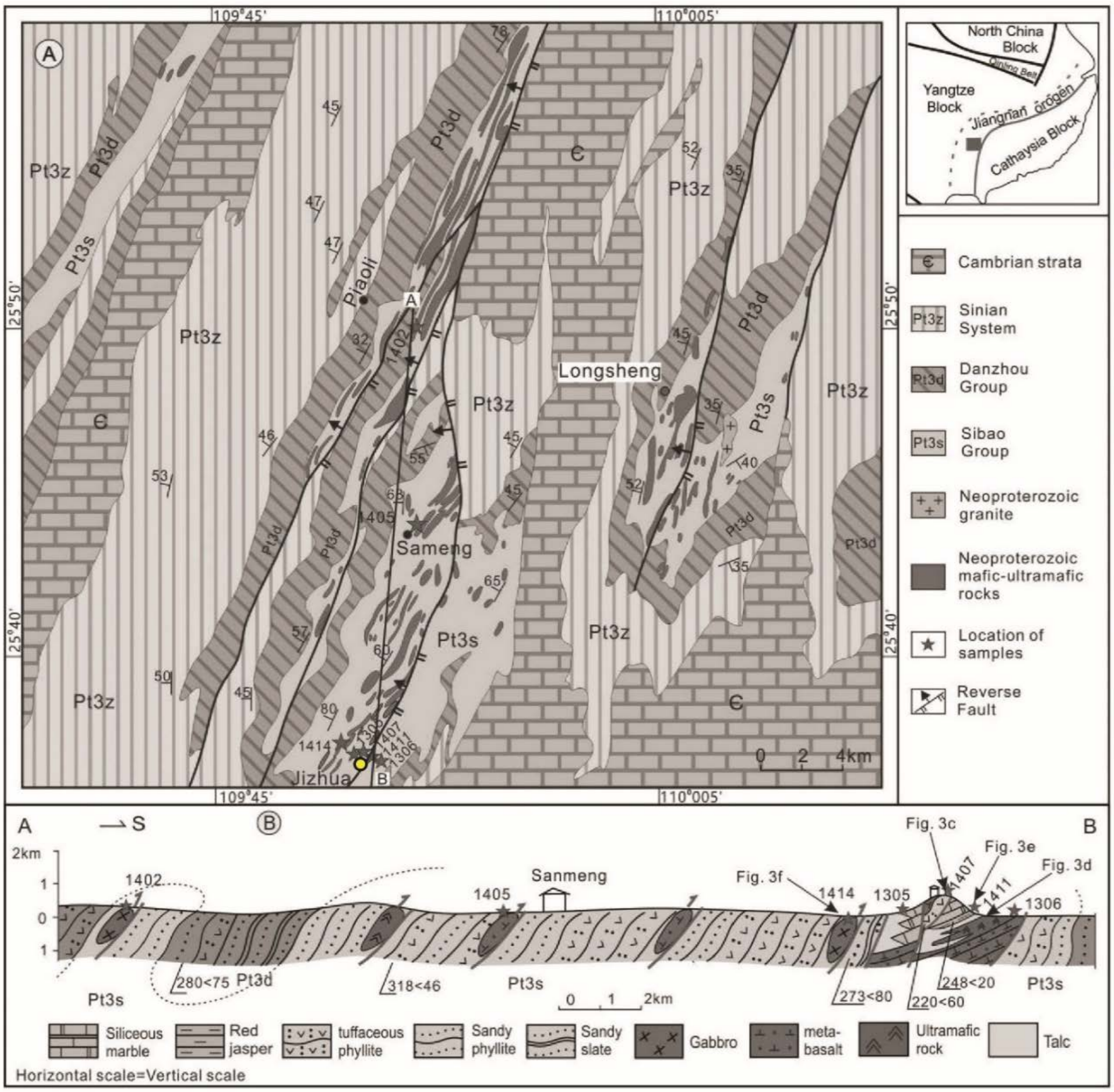


Figure 12. Geologic map from Yao et al. (2016) showing location of Jizhua (yellow dot) in Longsheng County, Guangxi Province, China. Talc deposits used in Johnson's Baby Powder and Shower to Shower are within the Danzhou Group.

Based on U-Pb zircon radiometric age constraints, the Danzhou Group was deposited sometime in the Neoproterozoic in a rift environment (Yao et al., 2016). Metamorphic mineral assemblages in the mafic rocks (e.g., albite, actinolite) indicate that the maximum grade of metamorphism experienced by the Danzhou Group hosting the talc deposits is greenschist-facies (medium pressure and maximum temperatures up to ~500°C; Figure 6). The talc deposits are spatially associated with thrust faults, including ductile shear zones, that formed during a collisional orogeny ~490–400 million years ago (Zhao et al., 2018). Deformation and metamorphism in the presence of Si-rich and H_20 and CO_2-bearing fluids facilitated metasomatism of the dolomitic marbles adjacent to the metabasalts to form the high-purity talc deposits (Li, 1979; Yao et al., 2016). Modeling of the metamorphic reactions indicates that some Mg needed to form the high-purity talc ores was supplied by the mafic rocks adjacent to the ore bodies (Li, 1979).

The descriptions of the geology and conditions of metamorphism in the published literature are consistent with that in the IMERYS413792 report for the Jizhua, Tongzishan, Guping, and Shanglang mines. While non-asbestiform tremolite and actinolite are reported in metabasalts (spillite) adjacent to the talc deposits by Li (1979) and IMERYS413792, respectively, none of the sources cited above detail any asbestiform minerals associated with the Longsheng talc deposits in the Danzhou Group, and there is no petrologic reason to predict the presence of asbestos.

6.0 Conclusions

Based on my knowledge of petrologic systems, extensive searching and evaluation of the published scientific literature, and examination of limited industry reports, it is my opinion to a reasonable degree of scientific certainty that the cosmetic talc sources used for Johnson’s Baby Powder and Shower to Shower were limited to mines that were free of asbestiform minerals. Overwhelmingly, the data I have evaluated and described above weighs in favor of the conclusion that there is no scientific merit to any claims of asbestos in the cosmetic talc ores utilized. Based on reviews of the geology associated with the mines and the pressure and temperature histories recorded by the rocks, the amphiboles found in Johnson’s Baby Powder and Shower to Shower derived from the Fontane, southern Vermont, and Guangxi talc mines would be incidental cleavage fragments from non-asbestiform amphiboles (i.e. prismatic or acicular), most likely derived from the margins (blackwall zones) of the talc deposits. Any such cleavage fragments are, in general, much less chemically-resistant and have different surface chemistries from their asbestiform counterparts, for which other distinctive properties include flexible bundles of fibrils with high tensile strength.

References Cited

Andreozzi, G. B., Pacella, A., Corazzari, I., Tomatis, M., & Turci, F. (2017). Surface reactivity of amphibole asbestos: a comparison between crocidolite and tremolite. *Scientific Reports*, *7*(1), 14696.

Arvidson, R. S., Ertan, I. E., Amonette, J. E., & Luttge, A. (2003). Variation in calcite dissolution rates: A fundamental problem? *Geochimica et cosmochimica acta*, *67*(9), 1623-1634.

Bain, G. W. (1942). Vermont talc and asbestos deposits. *Ore deposits as related to structural features. Princeton University Press, Princeton, New Jersey*, 255-258.

Bandli, B. R., & Gunter, M. E. (2014). Scanning electron microscopy and transmitted electron backscatter diffraction examination of asbestos standard reference materials, amphibole particles of differing morphology, and particle phase discrimination from talc ores. *Microscopy and Microanalysis*, *20*(6), 1805-1816.

Belluso, E., Cavallo, A., & Halterman, D. (2017). Crystal habit of mineral fibres. In *Mineral Fibres: Crystal Chemistry, Chemical-Physical Properties, Biological Interaction and Toxicity* (Vol. 18, pp. 65-109). European Mineralogical Union-EMU Notes in Mineralogy.

Blount, A. M. (1991). Amphibole content of cosmetic and pharmaceutical talcs. *Environmental health perspectives*, 94, 225.

Bozhilov, K. N. (2013). Structures and microstructures of non-classical pyriboles. *EMU Notes Mineral*, 14, 109-152.

Brown, B. M., & Gunter, M. E. (2003). Morphological and optical characterization of amphiboles from Libby, Montana USA by spindle stage assisted-polarized light microscopy. *The Microscope*, *53*(3), 121-140.

Buzon, M. E. (2016). *Talc characterization: A provenance study*. University of Idaho.

Cadoppi, P., Camanni, G., Balestro, G., & Perrone, G. (2016). Geology of the Fontane talc mineralization (Germanasca valley, Italian Western Alps). *Journal of Maps*, *12*(5), 1170-1177.

Cady, W. M., Albee, A. L., & Chidester, A. H. (1963). *Bedrock geology and asbestos deposits of the upper Missisquoi Valley and vicinity, Vermont* (No. 1122-B). US Geological Survey.

Campbell, W. J. (1977). Identification of selected silicate minerals and their asbestiform varieties. *National Bureau of Standards, Special Publication*, 506, 201-221.

Chang, P. H., Ern, H. Jr., Thompson, J.B. Jr. (1965). *Bedrock geology of the Woodstock quadrangle, Vermont,* 65 p., 2 plates.

Chatfield, E. J. (2018). Measurement of elongate mineral particles: What we should measure and how do we do it? *Toxicology and applied pharmacology*, 361, 36-46.

Chidester, A. H., Albee, A. L., & Cady, W. M. (1978). *Petrology, structure, and genesis of the asbestos-bearing ultramafic rocks of the Belvidere Mountain area in Vermont* (No. 1016). US Govt. Print. Off.

Chidester, A. H., Billings, M. P., & Cady, W. M. (1951). *Talc Investigations in Vermont Preliminary Report*. US Geological Survey.

Chidester, A. H., and Shride A. F. (1962). *Asbestos in the United States*, US Geological Survey. 12 pp.

Crane, D. T. (1992). *Polarized Light Microscopy of Asbestos*. Branch of Physical Measurements and Analysis OSHA Salt Lake Technical Center, Salt Lake City, Utah. Revised in 1995. https://www.osha.gov/dts/sltc/methods/inorganic/id191/id191.html

Del Greco, O., & Pelizza, S. (1984). The underground Fontane Talc Mine: main characteristics of the deposit and exploitation methods. *Bollettino dell'Associazione Mineraria Subalpina*, *21*, 85-92.

Doll, C. G., Billings, M. P., Cady, W. M., & Thompson, J. B. (Eds.). (1961). *Centennial geologic map of Vermont*. Vermont Geological Survey, Vermont Development Department.

Dorling, M., & Zussman, J. (1987). Characteristics of asbestiform and non-asbestiform calcic amphiboles. *Lithos*, *20*(6), 469-489.

Evans, B. W. (2004). The serpentinite multisystem revisited: chrysotile is metastable. *International Geology Review*, *46*(6), 479-506.

Fiume, M. M., Boyer, I., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., ... & Snyder, P. W. (2015). Safety assessment of talc as used in cosmetics. *International journal of toxicology*, 34(1_suppl), 66S-129S.

Gasco, I., Borghi, A., & Gattiglio, M. (2011). P–T Alpine metamorphic evolution of the Monte Rosa nappe along the Piedmont Zone boundary (Gressoney Valley, NW Italy). *Lithos*, *127*(1-2), 336-353.

Gillson, J. L. (1927). Origin of the Vermont talc deposits, with a discussion on the formation of talc in general. *Economic Geology*, *22*(3), 246-287.

Gualtieri, A. F., Pollastri, S., Gandolfi, N. B., & Gualtieri, M. L. (2018). In vitro acellular dissolution of mineral fibres: A comparative study. *Scientific reports*, *8*(1), 7071.

Harper, M. (2008). 10th Anniversary critical review: Naturally occurring asbestos. *Journal of Environmental Monitoring*, *10*(12), 1394-1408.

Harper, M., Butler, C., Berry, D., & Wroble, J. (2015). Where occupation and environment overlap: US Forest Service worker exposure to Libby Amphibole fibers. *Journal of occupational and environmental hygiene*, *12*(5), D47-D53.

Hess, H. H. (1933). The problem of serpentinization and the origin of certain chrysotile asbestos, talc, and soapstone deposits. *Economic Geology*, *28*(7), 634-657.

Honsberger, I. W., & Laird, J. (2018). Net-Transfer Reactions and Modal Spaces for Ultramafic Slivers, Vermont Appalachians, USA. The Canadian Mineralogist, 56(5), 821-846.

Huang, P., & Fuerstenau, D. W. (2001). The effect of the adsorption of lead and cadmium ions on the interfacial behavior of quartz and talc. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *177*(2-3), 147-156.

Karabinos, P., Mygatt, E. S., Cook, S. M., & Student, M. (2010). Evidence for an orogen-parallel, normal-sense shear zone around the Chester dome, Vermont: a possible template for gneiss dome formation in the New England Appalachians, USA. *From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region. Edited by RP Tollo, MJ Bartholomew, JP Hibbard, and PM Karabinos. Geological Society of America Memoir*, *206*, 183-203.

Kelse, J. W., & Thompson, C. S. (1989). The regulatory and mineralogical definitions of asbestos and their impact on amphibole dust analysis. *American industrial hygiene association Journal*, *50*(11), 613-622.

Klein, C. (193). Rocks, minerals and a dusty world. In: Guthrie, GD.; Mossman, B., editors. *Health effects of mineral dusts*. Washington, DC. p. 7-59.

Klein, C., & Hurlbut Jr, C. S. (1993). *Manual of Mineralogy*, 681 p.

Labagnara, D., Patrucco, M., Rossetti, P., & Pellegrino, V. (2013). Predictive assessment of the asbestos content in the Western Italian Alps: an essential tool for an effective approach to risk analysis and management in tunneling operations and muck reuse. *Environmental earth sciences*, 70(2), 857-868.

Lacinska, A. M., Styles, M. T., Bateman, K., Wagner, D., Hall, M. R., Gowing, C., & Brown, P. D. (2016). Acid-dissolution of antigorite, chrysotile and lizardite for ex situ carbon capture and storage by mineralisation. *Chemical Geology*, *437*, 153-169.

Lasaga, A. C., & Luttge, A. (2001). Variation of crystal dissolution rate based on a dissolution stepwave model. *Science*, *291*(5512), 2400-2404.

Li, Y. Y. (1979). Discussion on the genesis of Longsheng talc mine. *Non-Metallic Mines, 1*, 16-20

Marconi, A., & Verdel, U. (1990). Asbestos content of talcs from Italian mines and fibre concentration in various commercial talcum powders used in Italy. In *Health Related Effects of Phyllosilicates* (pp. 107-115). Springer, Berlin, Heidelberg.

National Research Council. (1984). *Asbestiform fibers: Nonoccupational health risks*. National Academies Press.

Nesbitt, H. W., & Young, G. M. (1984). Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic considerations. *Geochimica et Cosmochimica Acta*, *48*(7), 1523-1534.

Nesse, W. D. (1991). *Introduction to Optical Mineralogy*: Oxford Univ. Press*,* 335.

Pawley, A. R., & Wood, B. J. (1995). The high-pressure stability of talc and 10 Å phase: potential storage sites for H2O in subduction zones. *American Mineralogist*, *80*(9-10), 998-1003.

Perry, E.L. (1929). *The geology of Bridgewater and Plymouth Townships, Vermont*, *in* Report of the state geologist on the mineral industries and geology of Vermont, 1927-1928: Burlington, Vt., Free Press Printing Co., p. 1-64.

Phillips, A. H., Hess, H. H. (1936). Metamorphic differentiation at contacts between serpentinite and siliceous country rocks. *Amer. miner.* 21, 333-62.

Pollastri, S., D'Acapito, F., Trapananti, A., Colantoni, I., Andreozzi, G. B., & Gualtieri, A. F. (2015). The chemical environment of iron in mineral fibres. A combined X-ray absorption and Mössbauer spectroscopic study. *Journal of hazardous materials*, *298*, 282-293.

Pollastri, S., Gigli, L., Ferretti, P., Andreozzi, G. B., Gandolfi, N. B., Pollok, K., & Gualtieri, A. F. (2017). The crystal structure of mineral fibres. 3. Actinolite asbestos. *Periodico di Mineralogia*, *86*(2), 89-98.

Rabbitt, J. C. (1948). A new study of the anthophyllite series. *American Mineralogist: Journal of Earth and Planetary Materials*, *33*(5-6), 263-323.

Rakovan, J. (2011). Word to the Wise: Serpentine, California's State Rock. *Rocks & Minerals*, *86*(1), 63-68.

Ratcliffe, N. M., Stanley, R. S., Gale, M. H., Thompson, P. J., Walsh, G. J., Rankin, D. W., Doolan, B. L., Kim, J., Merhtens, C. J., Aleinikoff, J. N., & McHone, J. G. (2011). *Bedrock geologic map of Vermont* (No. 3184). US Geological Survey.

Robinson, G. R., Van Gosen, B. S., & Foley, N. K. (2006). *Ultramafic-hosted Talc-Magnesite deposits*. US Geological Survey.

Ross, M., Langer, A. M., Nord, G. L., Nolan, R. P., Lee, R. J., Van Orden, D., & Addison, J. (2008). The mineral nature of asbestos. *Regulatory Toxicology and Pharmacology*, *52*(1), S26-S30.

Ross, M., & Nolan, R. P. (2003). History of asbestos discovery and use and asbestos-related disease in context with the occurrence of asbestos within ophiolite complexes. *Special Papers-Geological Society of America*, 447-470.

Sandrone, R., Borghi, A., Carosso, G., Morsetti, C., Tagliano, C., & Zucchetti, S. (1990). Geometry of the talc deposit of Fontane, and structural evolution of the area (Dora-Maira Massif, Western Alps). *Bollettino Associazione Mineraria Subalpina*, *27*, 45-62.

Sandrone, R., & Zucchetti, S. (1988). Geology of the Italian high-quality cosmetic talc from the Pinerolo district (Western Alps). In *Proceedings of Symposium "Zuffardi'days", Cagliari*.

Sanford, R. F. (1982). Growth of ultramafic reaction zones in greenschist to amphibolite facies metamorphism. *American Journal of Science*, *282*(5), 543-616.

Schott, J., Brantley, S., Crerar, D., Guy, C., Borcsik, M., & Willaime, C. (1989). Dissolution kinetics of strained calcite. *Geochimica et Cosmochimica Acta*, *53*(2), 373-382.

Thompson Jr, J. B. (1970). Recent discussions of pyroxenes and amphiboles-Abstracts. *American Mineralogist*, *55*(1-2), 292-297.

Thompson, J. B. (1978). Biopyriboles and polysomatic series. *American Mineralogist*, *63*(3-4), 239-249.

Van Gosen et al. (2004). Using the geologic setting of talc deposits as an indicator of amphibole asbestos content. *Environmental Geology*. 45:920-939.

Van Gosen, B. S. (2006). *Reported historic asbestos mines, historic asbestos prospects, and natural asbestos occurrences in the Eastern United States* U.S. Geological Survey Open-File Report (No. 2005–1189) 1 plate. Includes supplementary materials. https://pubs.usgs.gov/of/2005/1189/.

Veblen, D. R. (1991). Polysomatism and polysomatic series; a review and applications. *American Mineralogist*, *76*(5-6), 801-826.

Veblen, D. R., & Burnham, C. W. (1978). New biopyriboles from Chester, Vermont; I, Descriptive mineralogy. *American Mineralogist*, *63*(9-10), 1000-1009.

Veblen, D. R., & Wylie, A. G. (1993). Mineralogy of amphiboles and 1:1 layer silicates. Mineralogical Society of America *Reviews in Mineralogy*, 28, Washington, DC (United States).

Walker, J. S., & Zoltai, T. (1979). A comparison of asbestos fibers with synthetic crystals known as "whiskers". *Annals of the New York Academy of Sciences*, *330*(1), 687-704.

Webb, L. E., Baldwin, S. L., & Fitzgerald, P. G. (2014). The Early-Middle Miocene subduction complex of the Louisiade Archipelago, southern margin of the Woodlark Rift. *Geochemistry, Geophysics, Geosystems*, 15(10), 4024-4046.

Webb, L. E., Johnson, C. L., & Minjin, C. (2010). Late Triassic sinistral shear in the East Gobi fault zone, Mongolia. *Tectonophysics*, 495(3-4), 246-255.

Webb, L. E., Hacker, B. R., Ratschbacher, L., McWilliams, M. O., & Dong, S. (1999). Thermochronologic constraints on deformation and cooling history of high-and ultrahigh-pressure rocks in the Qinling-Dabie orogen, eastern China. *Tectonics*, 18(4), 621-638.

Winter, J.D., 2001, *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall

Wylie, A. G. (1979). Fiber length and aspect ratio of some selected asbestos samples. *Annals of the New York Academy of Sciences*, *330*(1), 605-610.

Wylie, A. G. (2016). Amphibole Dusts: Fibers, Fragments, and Mesothelioma. *The Canadian Mineralogist*, *54*(6), 1403-1435.

Wylie, A. G., & Candela, P. A. (2015). Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and nonasbestiform amphibole and serpentine in ambient air and water. *Journal of Toxicology and Environmental Health, Part B*, *18*(1), 1-42.

Wylie, A. G., & Candela, P. A. (2015). Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and nonasbestiform amphibole and serpentine in ambient air and water. *Journal of Toxicology and Environmental Health, Part B*, *18*(1), 1-42.

Yao, J., Cawood, P. A., Shu, L., Santosh, M., & Li, J. (2016). An early Neoproterozoic accretionary prism ophiolitic mélange from the western Jiangnan Orogenic Belt, South China. *The Journal of Geology*, 124(5), 587-601.

Zhao, Z., Xu, Z., Ma, X., Liang, F., & Guo, P. (2018). Neoproterozoic–Early Paleozoic Tectonic Evolution of the South China Craton: New Insights from the Polyphase Deformation in the Southwestern Jiangnan Orogen. *Acta Geologica Sinica-English Edition*, 92(5), 1700-1727.

Zoltai, T. (1978). History of asbestos-related mineralogical terminology. In *Workshop on Asbestos: Definitions and Measurement Methods. National Bureau of Standards, Special Publication* (Vol. 506, pp. 1-18).

Zoltai, T. (1979). Asbestiform and acicular mineral fragments. *Annals of the New York Academy of Sciences*, *330*(1), 621-643.

Zoltai, T. (1981). Amphibole asbestos mineralogy. *Reviews in Mineralogy and Geochemistry*, *9*(1), 237-278.

Materials Considered

Armstrong, T. R., & Tracy, R. J. (2000). One-dimensional thermal modelling of Acadian metamorphism in southern Vermont, USA. *Journal of Metamorphic Geology*, *18*(6), 625-638.

Arvidson, R. S., Ertan, I. E., Amonette, J. E., & Luttge, A. (2003). Variation in calcite dissolution rates: A fundamental problem? *Geochimica et cosmochimica acta*, *67*(9), 1623-1634.

Aust, A. E., Cook, P. M., & Dodson, R. F. (2011). Morphological and chemical mechanisms of elongated mineral particle toxicities. *Journal of Toxicology and Environmental Health, Part B*, *14*(1-4), 40-75.

Bain, G. W. (1934). Serpentinization, origin of certain asbestos, talc, and soapstone deposits; discussion. *Economic Geology*, *29*(4), 397-400.

Bain, G. W. (1936). Serpentinization of Vermont Ultrabasics. *Bulletin of the Geological Society of America*, 47(12), 1961-1980.

Bain, G. W. (1942). Vermont talc and asbestos deposits. *Ore deposits as related to structural features. Princeton University Press, Princeton, New Jersey*, 255-258.

Bandli, B. R., & Gunter, M. E. (2014). Scanning electron microscopy and transmitted electron backscatter diffraction examination of asbestos standard reference materials, amphibole particles of differing morphology, and particle phase discrimination from talc ores. *Microscopy and Microanalysis*, *20*(6), 1805-1816.

Baronnet, A., & Belluso, E. (2002). Microstructures of the silicates: key information about mineral reactions and a link with the Earth and materials sciences. *Mineralogical Magazine*, 66(5), 709-732.

Belluso, E., Cavallo, A., & Halterman, D. (2017). Crystal habit of mineral fibres. In *Mineral Fibres: Crystal Chemistry, Chemical-Physical Properties, Biological Interaction and Toxicity* (Vol. 18, pp. 65-109). European Mineralogical Union-EMU Notes in Mineralogy.

Berner, R. A., & Schott, J. (1982). Mechanism of pyroxene and amphibole weathering; II, Observations of soil grains. American Journal of Science, 282(8), 1214-1231.

Blount, A. M. (1991). Amphibole content of cosmetic and pharmaceutical talcs. *Environmental health perspectives*, 94, 225.

Bozhilov, K. N. (2013). Structures and microstructures of non-classical pyriboles. *EMU Notes Mineral*, 14, 109-152.

Brown, B. M., & Gunter, M. E. (2003). Morphological and optical characterization of amphiboles from Libby, Montana USA by spindle stage assisted-polarized light microscopy. *The Microscope*, *53*(3), 121-140.

Buzon, M. E. (2016). *Talc characterization: A provenance study*. University of Idaho.

Cadoppi, P., Camanni, G., Balestro, G., & Perrone, G. (2016). Geology of the Fontane talc mineralization (Germanasca valley, Italian Western Alps). *Journal of Maps*, *12*(5), 1170-1177.

Cady, W. M., Albee, A. L., & Chidester, A. H. (1963). *Bedrock geology and asbestos deposits of the upper Missisquoi Valley and vicinity, Vermont* (No. 1122-B). US Geological Survey.

Campbell, W. J. (1977). Identification of selected silicate minerals and their asbestiform varieties. *National Bureau of Standards, Special Publication*, 506, 201-221.

Cavallo, G. J. (1989). X-ray investigation of" mountain leather". *The Canadian Mineralogist*, 27(2), 237-239.

Chang, P. H., Ern, H. Jr., Thompson, J.B. Jr. (1965). *Bedrock geology of the Woodstock quadrangle, Vermont,* 65 p., 2 plates.

Chatfield, E. J. (2018). Measurement of elongate mineral particles: What we should measure and how do we do it? *Toxicology and applied pharmacology*, 361, 36-46.

Chidester, A. H. (1962). *Petrology and geochemistry of selected talc-bearing ultramafic rocks and adjacent country rocks in north-central Vermont* (No. 345). US Govt. Print. Off.,.

Chidester, A. H., Albee, A. L., & Cady, W. M. (1978). *Petrology, structure, and genesis of the asbestos-bearing ultramafic rocks of the Belvidere Mountain area in Vermont* (No. 1016). US Govt. Print. Off.

Chidester, A. H., Billings, M. P., & Cady, W. M. (1951). *Talc Investigations in Vermont Preliminary Report*. US Geological Survey.

Chidester, A. H., Engel, A. E. J., & Wright, L. A. (1964). *Talc resources of the United States* (No. 1167). US Government Printing Office.

Chidester, A. H., and Shride A. F. (1962). *Asbestos in the United States*, US Geological Survey. 12 pp.

Cogulu, E., & Laurent, R. (1984). Mineralogical and chemical variations in chrysotile veins and peridotite host-rocks from the asbestos belt of southern Quebec. *The Canadian Mineralogist*, 22(1), 173-183.

Coish, R. A., & Gardner, P. (2004). Suprasubduction-zone peridotite in the northern USA Appalachians: evidence from mineral composition. *Mineralogical Magazine*, 68(4), 699-708.

Crane, D. T. (1992). *Polarized Light Microscopy of Asbestos*. Branch of Physical Measurements and Analysis OSHA Salt Lake Technical Center, Salt Lake City, Utah. Revised in 1995. https://www.osha.gov/dts/sltc/methods/inorganic/id191/id191.html

Del Greco, O., & Pelizza, S. (1984). The underground Fontane Talc Mine: main characteristics of the deposit and exploitation methods. *Bollettino dell'Associazione Mineraria Subalpina*, *21*, 85-92.

Development Review Board Minutes, Town of Ludlow, Vermont, May 11, 2015. https://www.ludlow.vt.us/vertical/sites/%7B78E8DA21-0D46-4486-AF59-9D2B5A1048F3%7D/uploads/DRB_Minutes_May_11_2015.pdf

Doll, C. G., Billings, M. P., Cady, W. M., & Thompson, J. B. (Eds.). (1961). *Centennial geologic map of Vermont*. Vermont Geological Survey, Vermont Development Department.

Dorling, M., & Zussman, J. (1987). Characteristics of asbestiform and non-asbestiform calcic amphiboles. *Lithos*, *20*(6), 469-489.

Evans, B. W. (2004). The serpentinite multisystem revisited: chrysotile is metastable. *International Geology Review*, *46*(6), 479-506.

Evans, B. W., & Ghiorso, M. S. (1995). Thermodynamics and petrology of cummingtonite. *American Mineralogist*, 80(7-8), 649-663.

Ferrini, V., Masi, U., & MONTICELLI, F. (1991). Geochemistry of pyrite from the talc deposit of Val Germanasca (Western Alps, Italy) and genetic implications. *Mineralogica et petrographica acta*, 34, 153-158.

Fiume, M. M., Boyer, I., Bergfeld, W. F., Belsito, D. V., Hill, R. A., Klaassen, C. D., ... & Snyder, P. W. (2015). Safety assessment of talc as used in cosmetics. *International journal of toxicology*, 34(1_suppl), 66S-129S.

Gale, M. H. (1980). *Geology of the Belvidere Mountain Complex, Eden and Lowell, Vermont (No. 80-978).* US Geological Survey.

Gasco, I., Borghi, A., & Gattiglio, M. (2011). P–T Alpine metamorphic evolution of the Monte Rosa nappe along the Piedmont Zone boundary (Gressoney Valley, NW Italy). *Lithos*, *127*(1-2), 336-353.

Gillson, J. L. (1927). Origin of the Vermont talc deposits, with a discussion on the formation of talc in general. *Economic Geology*, *22*(3), 246-287.

Greene, R. C. (1995). *Talc resources of the conterminous United States* (No. 95-586). US Geological Survey.

Gualtieri, A. F., Pollastri, S., Gandolfi, N. B., & Gualtieri, M. L. (2018). In vitro acellular dissolution of mineral fibres: A comparative study. *Scientific reports*, *8*(1), 7071.

Gunter, M. E., Belluso, E., & Mottana, A. (2007). Amphiboles: Environmental and health concerns. *Reviews in mineralogy and geochemistry*, *67*(1), 453-516.

Guthrie Jr, G. D. (1997). Mineral properties and their contributions to particle toxicity. *Environmental Health Perspectives*, 105(suppl 5), 1003-1011.

Hacker, B. R., & Christie, J. M. (1990). Brittle/ductile and plastic/cataclastic transitions in experimentally deformed and metamorphosed amphibolite. *Geophysical Monograph*, *56*, 127-147.

Hardy, J. A., & Aust, A. E. (1995). Iron in asbestos chemistry and carcinogenicity. *Chemical Reviews*, *95*(1), 97-118.

Harper, M. (2008). 10th Anniversary critical review: Naturally occurring asbestos. *Journal of Environmental Monitoring*, *10*(12), 1394-1408.

Harper, M., Butler, C., Berry, D., & Wroble, J. (2015). Where occupation and environment overlap: US Forest Service worker exposure to Libby Amphibole fibers. *Journal of occupational and environmental hygiene*, *12*(5), D47-D53.

Harper, M., Lee, E. G., Slaven, J. E., & Bartley, D. L. (2012). An inter-laboratory study to determine the effectiveness of procedures for discriminating amphibole asbestos fibers from amphibole cleavage fragments in fiber counting by phase-contrast microscopy. *Annals of occupational hygiene*, *56*(6), 645-659.

Hess, H. H. (1933). The problem of serpentinization and the origin of certain chrysotile asbestos, talc, and soapstone deposits. *Economic Geology*, *28*(7), 634-657.

Hodgson, A. A. (1977). Nature and paragenesis of asbestos minerals. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, 286(1336), 611-624.

Hoffman, M. A., & Walker, D. (1978). Textural and chemical variations of olivine and chrome spinel in the East Dover ultramafic bodies, south-central Vermont. *Geological Society of America Bulletin*, 89(5), 699-710.

Honsberger, I. W., & Laird, J. (2018). Net-Transfer Reactions and Modal Spaces for Ultramafic Slivers, Vermont Appalachians, USA. The Canadian Mineralogist, 56(5), 821-846.

Huang, P., & Fuerstenau, D. W. (2001). The effect of the adsorption of lead and cadmium ions on the interfacial behavior of quartz and talc. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *177*(2-3), 147-156.

Johannes, W. (1968). Experimental investigation of the reaction forsterite+ H 2 O⇌ serpentine+ brucite. *Contributions to Mineralogy and Petrology*, 19(4), 309-315.

Ilgren, E. B. (2004). The biology of cleavage fragments: a brief synthesis and analysis of current knowledge. *Indoor and Built Environment*, *13*(5), 343-356.

Karabinos, P., Macdonald, F. A., & Crowley, J. L. (2017). Bridging the gap between the foreland and hinterland I: Geochronology and plate tectonic geometry of Ordovician magmatism and terrane accretion on the Laurentian margin of New England. *American Journal of Science*, *317*(5), 515-554.

Karabinos, P., Mygatt, E. S., Cook, S. M., & Student, M. (2010). Evidence for an orogen-parallel, normal-sense shear zone around the Chester dome, Vermont: a possible template for gneiss dome formation in the New England Appalachians, USA. *From Rodinia to Pangea: The Lithotectonic Record of the Appalachian Region. Edited by RP Tollo, MJ Bartholomew, JP Hibbard, and PM Karabinos. Geological Society of America Memoir*, *206*, 183-203.

Keith, S. B., & Bain, G. W. (1932). Chrysotile asbestos; I, Chrysotile veins. *Economic Geology*, *27*(2), 169-188.

Kelse, J. W., & Thompson, C. S. (1989). The regulatory and mineralogical definitions of asbestos and their impact on amphibole dust analysis. *American industrial hygiene association Journal*, *50*(11), 613-622.

Klein, C. (1993). Rocks, minerals and a dusty world. In: Guthrie, GD.; Mossman, B., editors. *Health effects of mineral dusts*. Washington, DC. p. 7-59.

Klein, C., & Hurlbut Jr, C. S. (1993). *Manual of Mineralogy*, 681 p.

Labagnara, D., Patrucco, M., Rossetti, P., & Pellegrino, V. (2013). Predictive assessment of the asbestos content in the Western Italian Alps: an essential tool for an effective approach to risk analysis and management in tunneling operations and muck reuse. *Environmental earth sciences*, 70(2), 857-868.

Lacinska, A. M., Styles, M. T., Bateman, K., Wagner, D., Hall, M. R., Gowing, C., & Brown, P. D. (2016). Acid-dissolution of antigorite, chrysotile and lizardite for ex situ carbon capture and storage by mineralisation. *Chemical Geology*, *437*, 153-169.

Lasaga, A. C., & Luttge, A. (2001). Variation of crystal dissolution rate based on a dissolution stepwave model. *Science*, *291*(5512), 2400-2404.

Levitan, D. M., Hammarstrom, J. M., Gunter, M. E., Seal, R. R., Chou, I. M., & Piatak, N. M. (2009). Mineralogy of mine waste at the Vermont asbestos group mine, Belvidere Mountain, Vermont. *American Mineralogist*, *94*(7), 1063-1066.

Li, Y. Y. (1979). Discussion on the genesis of Longsheng talc mine. *Non-Metallic Mines, 1*, 16-20

Marconi, A., & Verdel, U. (1990). Asbestos content of talcs from Italian mines and fibre concentration in various commercial talcum powders used in Italy. In *Health Related Effects of Phyllosilicates* (pp. 107-115). Springer, Berlin, Heidelberg.

National Research Council. (1984). *Asbestiform fibers: Nonoccupational health risks*. National Academies Press.

Nesbitt, H. W., & Young, G. M. (1984). Prediction of some weathering trends of plutonic and volcanic rocks based on thermodynamic and kinetic considerations. *Geochimica et Cosmochimica Acta*, *48*(7), 1523-1534.

Nesse, W. D. (1991). *Introduction to Optical Mineralogy*: Oxford Univ. Press, 335.

Pawley, A. R., & Wood, B. J. (1995). The high-pressure stability of talc and 10 Å phase: potential storage sites for H2O in subduction zones. *American Mineralogist*, *80*(9-10), 998-1003.

Peretti, L. (1966). Geology and genesis of the talc deposits in the Pinerolese. *Bulletin of the Subalpine Mining Association, 3*, 283-304.

Perry, E.L. (1929). *The geology of Bridgewater and Plymouth Townships, Vermont*, *in* Report of the state geologist on the mineral industries and geology of Vermont, 1927-1928: Burlington, Vt., Free Press Printing Co., p. 1-64.

Phillips, A. H., Hess, H. H. (1936). Metamorphic differentiation at contacts between serpentinite and siliceous country rocks. *Amer. miner.* 21, 333-62.

Plumlee, G. S., Morman, S. A., & Ziegler, T. L. (2006). The toxicological geochemistry of earth materials: an overview of processes and the interdisciplinary methods used to understand them. *Reviews in Mineralogy and Geochemistry*, *64*(1), 5-57.

Pollastri, S., D'Acapito, F., Trapananti, A., Colantoni, I., Andreozzi, G. B., & Gualtieri, A. F. (2015). The chemical environment of iron in mineral fibres. A combined X-ray absorption and Mössbauer spectroscopic study. *Journal of hazardous materials*, *298*, 282-293.

Pollastri, S., Gigli, L., Ferretti, P., Andreozzi, G. B., Gandolfi, N. B., Pollok, K., & Gualtieri, A. F. (2017). The crystal structure of mineral fibres. 3. Actinolite asbestos. *Periodico di Mineralogia*, *86*(2), 89-98.

Rabbitt, J. C. (1948). A new study of the anthophyllite series. *American Mineralogist: Journal of Earth and Planetary Materials*, *33*(5-6), 263-323.

Rakovan, J. (2011). Word to the Wise: Serpentine, California's State Rock. *Rocks & Minerals*, *86*(1), 63-68.

Ratcliffe, N. M., & Armstrong, T. R. (2001). Bedrock geologic map of the Saxtons River 7.5′× 15′ quadrangle. *Windam and Windsor Counties, Vermont: United States Geological Survey Investigations Series Map I-2636, scale*, *1*(24,000).

Ratcliffe, N. M., Stanley, R. S., Gale, M. H., Thompson, P. J., Walsh, G. J., Rankin, D. W., Doolan, B. L., Kim, J., Merhtens, C. J., Aleinikoff, J. N., & McHone, J. G. (2011). *Bedrock geologic map of Vermont* (No. 3184). US Geological Survey.

Robinson, G. R., Van Gosen, B. S., & Foley, N. K. (2006). *Ultramafic-hosted Talc-Magnesite deposits*. US Geological Survey.

Ross, M., Langer, A. M., Nord, G. L., Nolan, R. P., Lee, R. J., Van Orden, D., & Addison, J. (2008). The mineral nature of asbestos. *Regulatory Toxicology and Pharmacology*, *52*(1), S26-S30.

Ross, M., & Nolan, R. P. (2003). History of asbestos discovery and use and asbestos-related disease in context with the occurrence of asbestos within ophiolite complexes. *Special Papers-Geological Society of America*, 447-470.

Sandrone, R., Borghi, A., Carosso, G., Morsetti, C., Tagliano, C., & Zucchetti, S. (1990). Geometry of the talc deposit of Fontane, and structural evolution of the area (Dora-Maira Massif, Western Alps). *Bollettino Associazione Mineraria Subalpina*, *27*, 45-62.

Sandrone, R., & Zucchetti, S. (1988). Geology of the Italian high-quality cosmetic talc from the Pinerolo district (Western Alps). In *Proceedings of Symposium "Zuffardi'days", Cagliari*.

Sanford, R. F. (1982). Growth of ultramafic reaction zones in greenschist to amphibolite facies metamorphism. *American Journal of Science*, *282*(5), 543-616.

Schott, J., Brantley, S., Crerar, D., Guy, C., Borcsik, M., & Willaime, C. (1989). Dissolution kinetics of strained calcite. *Geochimica et Cosmochimica Acta*, *53*(2), 373-382.

Siegrist Jr, H. G., & Wylie, A. G. (1980). Characterizing and discriminating the shape of asbestos particles. *Environmental research*, 23(2), 348-361.

Skrotzki, W. (1990). Microstructure in hornblende of a mylonitic amphibolite. Geological Society, London, Special Publications, 54(1), 321-325.

Thompson Jr, J. B. (1970). Recent discussions of pyroxenes and amphiboles-Abstracts. *American Mineralogist*, *55*(1-2), 292-297.

Thompson, J. B. (1978). Biopyriboles and polysomatic series. *American Mineralogist*, *63*(3-4), 239-249.

Thompson, B. D., Gunter, M. E., & Wilson, M. A. (2011). Amphibole asbestos soil contamination in the USA: A matter of definition. American Mineralogist, 96(4), 690-693.

USGS, (1994). The Mineral Industry of Vermont. *Minerals Yearbook*. 239-241 https://minerals.usgs.gov/minerals/pubs/state/985095.pdf

Van Gosen et al. (2004). Using the geologic setting of talc deposits as an indicator of amphibole asbestos content. *Environmental Geology*. 45:920-939.

Van Gosen, B. S. (2006). *Reported historic asbestos mines, historic asbestos prospects, and natural asbestos occurrences in the Eastern United States* U.S. Geological Survey Open-File Report (No. 2005–1189) 1 plate. Includes supplementary materials. https://pubs.usgs.gov/of/2005/1189/.

Veblen, D. R. (1991). Polysomatism and polysomatic series; a review and applications. *American Mineralogist*, *76*(5-6), 801-826.

Veblen, D. R., & Burnham, C. W. (1978). New biopyriboles from Chester, Vermont; I, Descriptive mineralogy. *American Mineralogist*, *63*(9-10), 1000-1009.

Veblen, D. R., & Wylie, A. G. (1993). Mineralogy of amphiboles and 1:1 layer silicates. Mineralogical Society of America *Reviews in Mineralogy*, 28, Washington, DC (United States).

Walker, J. S., & Zoltai, T. (1979). A comparison of asbestos fibers with synthetic crystals known as "whiskers". *Annals of the New York Academy of Sciences*, *330*(1), 687-704.

Webb, L. E., Baldwin, S. L., & Fitzgerald, P. G. (2014). The Early-Middle Miocene subduction complex of the Louisiade Archipelago, southern margin of the Woodlark Rift. *Geochemistry, Geophysics, Geosystems*, 15(10), 4024-4046.

Webb, L. E., Johnson, C. L., & Minjin, C. (2010). Late Triassic sinistral shear in the East Gobi fault zone, Mongolia. *Tectonophysics*, 495(3-4), 246-255.

Webb, L. E., Hacker, B. R., Ratschbacher, L., McWilliams, M. O., & Dong, S. (1999). Thermochronologic constraints on deformation and cooling history of high-and ultrahigh-pressure rocks in the Qinling-Dabie orogen, eastern China. *Tectonics*, 18(4), 621-638.

Winter, J.D., 2001, *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall

Wylie, A. G. (1979). Fiber length and aspect ratio of some selected asbestos samples. *Annals of the New York Academy of Sciences*, *330*(1), 605-610.

Wylie, A. G. (2016). Amphibole Dusts: Fibers, Fragments, and Mesothelioma. *The Canadian Mineralogist*, *54*(6), 1403-1435.

Wylie, A. G., & Candela, P. A. (2015). Methodologies for determining the sources, characteristics, distribution, and abundance of asbestiform and nonasbestiform amphibole and serpentine in ambient air and water. *Journal of Toxicology and Environmental Health, Part B*, *18*(1), 1-42.

Yao, J., Cawood, P. A., Shu, L., Santosh, M., & Li, J. (2016). An early Neoproterozoic accretionary prism ophiolitic mélange from the western Jiangnan Orogenic Belt, South China. *The Journal of Geology*, 124(5), 587-601.

Zhao, Z., Xu, Z., Ma, X., Liang, F., & Guo, P. (2018). Neoproterozoic–Early Paleozoic Tectonic Evolution of the South China Craton: New Insights from the Polyphase Deformation in the Southwestern Jiangnan Orogen. *Acta Geologica Sinica-English Edition*, 92(5), 1700-1727.

Zoltai, T. (1978). History of asbestos-related mineralogical terminology. In *Workshop on Asbestos: Definitions and Measurement Methods. National Bureau of Standards, Special Publication* (Vol. 506, pp. 1-18).

Zoltai, T. (1979). Asbestiform and acicular mineral fragments. *Annals of the New York Academy of Sciences*, *330*(1), 621-643.

Zoltai, T. (1981). Amphibole asbestos mineralogy. *Reviews in Mineralogy and Geochemistry*, *9*(1), 237-278.

Expert Report of Alan Campion, PhD (November 16, 2018)

Expert Report of Robert B. Cook, PhD (November 16, 2018)

Amended Expert Report of Robert B. Cook, PhD (January 22, 2019)

Robert Cook Deposition (January 30, 2019)

Expert Report of Mark Krekeler, PhD (November 16, 2018)

Addendum to the Expert Report of Mark Krekeler, PhD (January 17, 2019)

Mark Krekeler Deposition (January 25, 2019)

Expert Report of William E. Longo, PhD and Mark W. Rigler, PhD (November 14, 2018)

Supplementary Expert Report of William E. Longo, PhD & Mark W. Rigler, PhD (January 16, 2019)

FDP000000381

FDP000000495

IMERYS030231

IMERYS032139

IMERYS034036

IMERYS034115

IMERYS061692

IMERYS173933

IMERYS240978

IMERYS413792

IMERYS415991

JNJ000414760

JNJAZ55_000001979

JNJI4T5_000005147

JNJTALC000165964

JNJTALC000297537

JNJTALC000347819

http://www.science.smith.edu/geosciences/petrology/petrography/hornblende/P1010004.jpg

https://dec.vermont.gov/geological-survey/publication-gis/VTrock

https://usgsprobe.cr.usgs.gov/images/asbestos_2.jpg

https://usgsprobe.cr.usgs.gov/images/hexagonite.jpg

EXHIBIT A

Dr. Laura E. Webb

ORCID ID: 0000-0002-0597-5793 • ResearcherID: F-8226-2011
Associate Professor • Department of Geology • University of Vermont
180 Colchester Ave • Burlington, Vermont, 05405 USA
Phone: 802-656-8136 • Fax: 802-656-0045 • E-mail: lewebb@uvm.edu

EDUCATION

PhD in Geological and Environmental Sciences, Stanford University, Stanford, California, 1999. Doctoral Dissertation: "Exhumation of high and ultrahigh-pressure rocks in the Qinling–Dabie Orogen, eastern China and the Yagan–Onch Hayrhan metamorphic core complex, southern Mongolia." M.O. McWilliams, advisor. W.G. Ernst, S.A. Graham, and B.R. Hacker (UCSB), committee members.

BS in Geology, University of California, Los Angeles, *cum laude*, 1994.

APPOINTMENTS

Associate Professor, Department of Geology, University of Vermont, Burlington, Vermont, Fall 2014–present.

Assistant Professor, Department of Geology, University of Vermont, Burlington, Vermont, 2008–2014.

Graduate Faculty, University of Vermont, Burlington, Vermont, 2009–present.

PREVIOUS RESEARCH AND WORK EXPERIENCE

Research Assistant Professor, Department of Earth Sciences, Syracuse University, Syracuse, NY, 2004–2012.

Syracuse University Noble Gas Isotopic Research Laboratory Manager, Department of Earth Sciences, Syracuse University, Syracuse, NY, 2000–2008.

$^{40}Ar/^{39}Ar$ Laboratory Manager, University of Geneva, Switzerland, 1999–2000.

Staff Geologist, American Geotechnical, Anaheim, California, 1994.

AWARDED GRANTS AND CONTRACTS

2018–2021, DMR 1828371, National Science Foundation Major Research Instrumentation, $480,000: “MRI: Acquisition of a Variable-Pressure, Field-Emission Scanning Electron Microscope for Materials Research and Education” **Co-PI**. Collaborative with M. White (PI), C. Landry, R. Headrick, and F. Sansoz.

2016–2017, University of Vermont, College of Arts and Sciences, Seed Grant, $9843, Subduction–Exhumation History of the Tillotson Peak Complex, Vermont.” **PI.**

2010–2015, EAR 1028991, NSF Instrumentation and Facilities, $507,978: “Acquisition of a noble gas mass spectrometer and development of a multi-user facility for $^{40}Ar/^{39}Ar$ geochronology at the University of Vermont.” **PI**.

2010–2014, EAR 0948529, NSF Petrology and Geochemistry and co-sponsored by Tectonics, $194,493: “Collaborative Research: Constraining P-T-t-D paths of metamorphic tectonites

with the TitaniQ thermobarometer." **PI**. Collaborative research with F. Spear and J. Thomas (Rensselaer Polytechnic Institute).

2007–2014, EAR 0709054, NSF Continental Dynamics, $1,282,742: "Collaborative Research: How Is Rifting Exhuming the Youngest HP/UHP Rocks on Earth?" **Co-PI**. Collaborative with S. Baldwin (PI) and P. Fitzgerald (Syracuse University). Collaborative research with G. Abers, T. Plank, W.R. Buck & J. Gaherty (Columbia University), B. Hacker (UCSB), and P. Mann & B. Horton (UT Austin).

2009–2013, DUE 0941255, NSF Course Curriculum and Laboratory Improvement Program, $103,410: "Collaborative Research: Field-based Projects Exploring Geophysical Methods, with Applications to the State of Vermont." **PI**. Keith Klepeis, Co-PI. Collaborative research with D. Westerman and G. Springston (Norwich University; and the Vermont Geological Survey).

2006–2011, EAR 0537165 & EAR-0929902, NSF Tectonics, $267,223: "Collaborative Research: Strike-Slip History of the East Gobi Fault Zone, Mongolia: Modes of Intraplate Deformation, Sedimentary Basin Evolution, and Regional Fault Linkages". **PI.** Collaborative research with C. Johnson (University of Utah).

2004–2007, EAR 0345822, NSF Instrumentation and Facilities, $77,340: "Acquisition of an excimer laser system for Syracuse University Noble Gas Isotope Research Laboratory (SUNGIRL)". **Co-PI** with S. Baldwin.

TECHNICAL EXPERTISE

Nu Noblesse, MAP 216 and Micromass 5400 noble gas mass spectrometers for $^{40}Ar/^{39}Ar$ thermochronology.

Balzers Prisma QME 200 quadrupole mass spectrometer for (U-Th)/He thermochronology.

Design, construction, and maintenance of ultra-high vacuum extraction lines.

Management of radioactive materials and isotopic inventories.

Other analytical experience: electron microprobe analyses, secondary ionization mass spectrometry, laser ablation inductively couple mass spectrometry, cathodoluminescence imaging.

CONSULTING EXPERIENCE

2017–present: Formation of high-purity talc deposits mined for Johnson & Johnson talcum powders and their relationships, or lack thereof, to asbestos. Retained by law firms representing Johnson & Johnson in talc-related litigation.

COURSES REGULARLY TAUGHT AT UVM

*Denotes new courses at UVM developed by Webb

GEOL 161 Field Methods in Geophysics*. As of fall 2015, this is a recognized service-learning course and fulfills the University-wide sustainability general education requirement.

GEOL 231 Petrology

GEOL 240 Tectonics

GEOL 263 Geochronology*

GEOL 266 Microstructures*

GEOL 302 Introduction to Graduate Studies

INTERNATIONAL GEOLOGIC FIELD CAMPAIGNS

2011: Coastal batholith, Central Chile.
2010: Islands of the Woodlark Rise, southeastern Papua New Guinea.
2009: East Gobi Fault Zone, southern Mongolia.
2009: Louisiade Archipelago, southeastern Papua New Guinea.
2008: D'Entrecasteaux Islands, southeastern Papua New Guinea.
2004, 2006, 2007: East Gobi Fault Zone, southern Mongolia.
2002: Sulu ultrahigh-pressure terrane, Shandong peninsula, China.
1997, 1998: Southern Mongolia.
1994, 1995, 1996: Qinling–Dabie orogen, China.

HONORS, AWARDS AND PROFESSIONAL AFFILIATIONS

Member of: Geological Society of America, Mineralogical Society of America, American Geophysical Union, Vermont Geological Society, and American Association for the Advancement of Science.

Nominated for the 2018 Kroepsch-Maurice Excellence in Teaching Award at the associate professor level, University of Vermont.

2018 Awardee of "Outstanding New Service-Learning Faculty", Community-University Partnerships & Service-Learning (CUPS). Nominated for GEOL161 Field Methods in Geophysics course.

UVM Faculty Fellow for Service Learning, AY2014–2015. Participant in service learning workshops and working towards UVM designation of GEOL161 Field Methods in Geophysics as a service-learning course.

Featured in an article on NSF-funded research on titanium-in-quartz thermobarometry in *International Innovation*. "Under Pressure", *International Innovation*, North America, August 2012, Issue 3, pp. 120–122.

UVM Sustainability Faculty Fellow, 2012. Participant in program designed to foster integration of interdisciplinary approaches to sustainability into the UVM curriculum; enhance the understanding of sustainability concepts among those not trained in environmental fields; and to explore curriculum design strategies that will engage students in thinking about sustainability from a multidisciplinary perspective.

Nominated for the 2011 Kroepsch-Maurice Excellence in Teaching Award at the assistant professor level, University of Vermont.

PROFESSIONAL DEVELOPMENT AND WORKSHOPS

Participant in Scholarship of Teaching and Learning initiative (AY2017–2018). Development of Action Research project related to revision of GEOL 240 Tectonics course employing scaffolding approaches to facilitate student achievement of writing and information learning outcomes for Geology.

Designing for Learning Spring 2017 Cohort, University of Vermont. Participated in semester-long program for faculty to help identify and reduce student barriers to learning.

Co-convener of EarthScope synthesis workshop, *Synthesizing EarthScope Results: Develop a New Model for the 4-D Evolution of North America*, James Madison University, Harrisonburg, Virginia, November 2016.

Participant and breakout group synthesizer in the NSF-sponsored *Future of Tectonics Workshop*, University of Wisconsin, Madison, Wisconsin, May 2016.

Campuses for Environmental Stewardship, Faculty Development Institute and Training. November 5-6, 2015, Portland, Maine. Part of UVM team for development of sustainability service learning courses (participant in UVM subgrant from Maine Campus Compact project funded by the Davis Educational Foundation).

Participant in UVM Honors College Faculty Seminar, August 11–13, 2014: *'Big Data': Engaging and Critiquing the Production of Knowledge in the Digital Age*.

Outcomes of the Future of Geoscience Undergraduate Education Summit webinar participant, March, 2013.

EarthCube domain end-user workshop: Bringing Geochronology into the EarthCube framework. October, 2013, University of Wisconsin – Madison. Invited participant. The overall goal of the workshop is to: 1) identify the scientific challenges and opportunities facing the geochronology domain for next 5-15 years; 2) specify the data and cyber-infrastructure obstacles to meeting those challenges; 3) compile a list of known community data and modeling resources; 4) describe the data and cyber-capabilities required to meet challenges, by matching obstacles (2) with resources (3) and identifying/imagining unmet needs that may develop; and 5) develop ideas for at least two "proof-of-concept" projects or test cases for scientifically transformative activities that would become feasible if EarthCube is successful.

Systems, Society, Sustainability and the Geosciences Workshop. July 2012, Carleton College. This workshop is part of the InTeGrate project, a five-year, NSF-funded STEP Center grant geared towards increasing undergraduate geoscience literacy and "increase the number of majors in the geosciences and associated fields who are able to work with other scientists, social scientists, business people, and policy makers to develop viable solutions to current and future environmental and resource challenges."

Early Career Geoscience Faculty Workshop: Teaching, Research, and Managing Your Career. National Science Foundation On the Cutting Edge workshop series, College of William and Mary, 2008.

Participant in the NSF-funded *U.S.–Russia Workshop on the Plate Tectonic Evolution of Northeast Russia*. Stanford University, 2004.

Fourth International Symposium on Andean Geodynamics. University of Göttingen, Germany, 1999.

Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion. Penrose Conference, Greece, 1996.

Ultrahigh-Pressure Metamorphism and Tectonics workshops. Stanford University, 1994 and 1999.

PROFESSIONAL SERVICE AND EDUCATIONAL OUTREACH

National Science Foundation EarthScope Steering Committee, member. Fall 2015–present.

Member of the UVM General Education Sustainability Assessment Committee, Spring 2016–Present. Co-Chair of committee during AY2017–2018 and AY2018–2019.

Member of the Standard Four: Academic Program Committee for UVM's 10-year reaccreditation review from the New England Association of Schools and Colleges (NEASC) in 2019, AY2017–2018.

Session organizer and convener, “Orogenic Sutures—Recognition, Characterization, and Tectonic Implications”. Geological Society of America Northeastern Section Annual Meeting, Burlington, Vermont, March 2018.

Appointee to three-year term on the College of Arts and Sciences Deans Academic Planning and Budget Committee, Fall 2014–Spring 2017.

Co-convener of NSF EarthScope synthesis workshop: Synthesizing EarthScope Results to Develop a New Community Model for the 4-D Evolution of North America. November 18–20, 2016, at James Madison University, Harrisonburg, Virginia.

Department of Geology liaison for the Writing and Information Literacy in the Disciplines (WILD) General Education initiative, Spring 2014–Fall 2016.

Rock Point Funding and Staffing Committee, Land Use Implementation Plan, Spring 2015–2016.

Session organizer and convener, “Bridging Two Continents: Comparative Studies of Accretionary Orogenesis in the Central Asian Orogenic Belt, North American Cordillera, and Other Orogenic Belts”. Joint meeting of the Geological Society of America (GSA) and the Geological Society of China (GSC), 2015 GSA Annual Meeting, Baltimore, Maryland, November 2015.

NSF EarthScope 2015 National Meeting organizing committee member. Stowe, Vermont, June 2015.

NSF EarthScope 2015 National Meeting organizer and co-leader of conference field trip. Stowe, Vermont, June, 2015.

Regular reviewer of NSF proposals (2–5 per year typical; Tectonics, Instrumentation and Facilities, Integrated Earth Systems, Petrology and Geochemistry, EarthScope, and CAREER programs) and journal manuscripts (5–10 per year typical. Journals include: *Geology, Tectonics, Journal of Metamorphic Geology, Terra Nova, GSA Bulletin, Journal of Structural Geology, Journal of Geology, Lithos, Journal of Geophysical Research – Solid Earth, Tectonophysics, Geoscience Frontiers, Journal of Asian Earth Sciences, Earth Science Reviews,* and *European Journal of Mineralogy*).

Department of Geology Graduate Student Coordinator, 2010–2013.

Organizer of Geology Seminar Series, Department of Geology, University of Vermont, 2009–2013.

Session organizer and convener, “Innovations in Geochronology: Present Developments and a Vision for 2020.” 2013 Goldschmidt conference, Florence, Italy.

Member of the sustainability general education requirement committee charged with developing a suite of learning outcomes and methods of assessment for a university-wide sustainability general education requirement. 2013–2014.

UVM College of Arts and Sciences Academic Standing Committee, Fall 2010–Spring 2013.

Search committee member for Department of Geology tenure-track position in geochemistry, Spring 2013.

Earth Sciences proposal review panel member, National Science Foundation, Tectonics Program, served two single-term appointments in 2011 and 2012.

UVM College of Arts and Sciences summer orientation registration advising, 2009–2013.

Session organizer and convener, “The Wilson Cycle Revisited: From Microplates and Mobile Terranes to Supercontinent Dispersals.” 2010 American Geophysical Union Fall Meeting.

Search Committee member for Department of Geology Chairperson, Spring 2010.

Faculty Senator, University of Vermont, 2009–2010.

Advisor to Geology Club and the Eta Kappa Chapter of the Sigma Gamma Epsilon National Honor Society for Earth Sciences, University of Vermont, 2009–2010.

Session organizer and convener, "Intraplate Deformation and Sedimentary Basins: A Record of Plate Margin Processes?" 2009 American Geophysical Union Fall Meeting.

UVM coordinator for the Vermont Geological Society Spring Meeting, April 2009.

Organizer of Geoscience Career Workshop, Department of Geology, University of Vermont, April 2009.

Session organizer and convener, "Microplate Geodynamics." 2008 American Geophysical Union Fall Meeting.

INVITED LECTURES

November 2018, Johns Hopkins University, "Insights into polyphase deformation and fault reactivation from $^{40}Ar/^{39}Ar$ geochronology."

April 2018, University of Miami Ohio, "Punctuated melt-enhanced deformation and tectonic reactivation above a long-lived subduction zone, Coastal Andes, Central Chile."

October 2016, University of Iowa, **"**Structural and isotopic constraints on the development of a major Phanerozoic intraplate fault zone**".**

February 2016, University of Wisconsin, Madison**,** "Slippery when wet: Confessions of an intraplate fault zone."

March 2015, University of Massachusetts, Amherst, "How to look older than your age: Phanerozoic life in the fastlane of the East Gobi Fault Zone."

October 2014, invited lecture on $^{40}Ar/^{39}Ar$ geochronology, Geological Society of America short course "EarthScope: Geochronology and the Earth Sciences", 2014 GSA Annual Meeting, Vancouver, Canada.

March 2012, McGill University GEOTOP Seminar, "The Epic Saga of Tavan Har: Phanerozoic Continental Growth, Collisional Orogenesis, and Intraplate Deformation in Southeastern Mongolia."

March 2012, University of New Hampshire Randolph W. Chapman Colloquium, "The Epic Saga of Tavan Har: Phanerozoic Continental Growth, Collisional Orogenesis, and Intraplate Deformation in Southeastern Mongolia."

September 2009, Department of Geology, Colby College, "P-T-t-D Paths of Metamorphic Tectonites and Making the Leap from Micron to Plate Scale."

October 2008, Department of Geology, Middlebury College, "Can subduction be undone? Examining the role of microplate rotation in the exhumation of high and ultrahigh-pressure rocks in Papua New Guinea."

April 2008, Syracuse University College of Arts and Sciences Frontiers of Science Lecture Series, "How do plate boundaries evolve on Earth?"

February 2008, Department of Geology, University of Vermont, "What's under the rug? Unraveling the tectonic history of southeastern Mongolia."

November 2006, Department of Geology & Geography, West Virginia University, "Unraveling complex intraplate deformation in southeastern Mongolia."

PUBLICATIONS IN PEER-REVIEWED JOURNALS

Student authors indicated in italics

Klepeis, K.A., **Webb, L.E.**, *Blatchford, H.*, Schwartz, J., Jongens, R., Turnbull, R., and Stowell, H., *in review*, Crust-mantle interactions above the Puysegur subduction zone in Fiordland, New Zealand. GSA Today.

Brombin, V., Bonadiman, C., Jourdan, F., Roghi, G., Coltori, M., **Webb, L.E.**, Callegaro, S., Bellieni, G., De Vecchi, G., Sedea, R., Marzoli, A., *in revision*, Intraplate magmatism at a convergent plate boundary, the case of the Cenozoic northern Adria magmatism. Earth-Science Reviews.

Webb, L.E., and Klepeis, K.A., *in press*, $^{40}Ar/^{39}Ar$ constraints on the Tectonic evolution of the Late Paleozoic and Early Mesozoic accretionary complex of coastal Central Chile. Book chapter *in* Horton, B., and Folguera, A. eds. Andean Tectonics; Elsevier.

Cordova, J.L., Mulcahy, S.R., Schermer, E.R., and **Webb, L.E.**, 2018, Subduction initiation and early evolution of the Easton Metamorphic Suite, Northwest Cascades, Washington. Lithosphere, v. 11, no. 1, p. 44-58, doi.org/10.1130/L1009.1.

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, 2017, Plate interior polyphase fault systems and sedimentary basin evolution: Case study of the East Gobi Basin and East Gobi Fault Zone, southeastern Mongolia, Journal of Asian Earth Sciences, v. 151, p. 343–358, doi: 10.1016/j.jseaes.2017.05.017.

Webber, J.R., Klepeis, K.A., **Webb, L.E.**, Cembrano, J., Morata, D., Mora-Klepeis, G., and Arancibia, G., 2015, Deformation and magma transport in a crystallizing plutonic complex, Coastal Batholith, central Chile, Geosphere, v. 11, no. 5., p. 1401-1426.

Webb, L.E., Baldwin, S.L. and Fitzgerald, P.G., 2014, The Early–Middle Miocene subduction complex of the Louisiade Archipelago, southern margin of the Woodlark Rift. Geophysics, Geochemistry, Geosystems, doi: 10.1002/2014GC005500.

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, *Taylor, J.P.*, Jalbaa, U., and Minjin, C., 2014, Total and incremental left-lateral displacement across the East Gobi Fault Zone, southern Mongolia: implications for timing and modes of polyphase intracontinental deformation, Earth and Planetary Science Letters, v. 392, p. 1-15, doi: 10.1016/j.epsl.2014.01.016.

Ashley, K.T., **Webb, L.E.**, Spear, F.S., and Thomas, J.B., 2013, P-T-D histories from quartz: A case study of the application of the TitaniQ thermobarometer to progressive fabric development in metapelites, Geochemistry, Geophysics, Geosystems, v. 14, doi: 10.1002/ggge.20237.

Taylor, J., **Webb, L.**, Johnson, C., and *Heumann, M.*, 2013, The lost South Gobi Microcontinent: protolith studies of metamorphic tectonites and implications for the evolution of continental crust in southeastern Mongolia, Geosciences, special issue: Continental Accretion and Evolution, doi:10.3390/geosciences3030543.

Leech, M.L., and **Webb, L.E.**, 2013, Is the HP-UHP Hong'an-Dabie-Sulu orogen a piercing point for offset on the Tan-Lu fault? Journal of Asian Earth Sciences, v. 62, p. 112–129, DOI: 10.1016/j.jseaes.2012.08.005.

Spear, F., *Ashley, K.T.*, **Webb, L.E.**, and Thomas, J., 2012, Ti diffusion in quartz inclusions: implications for metamorphic time scales, Contributions to Mineralogy and Petrology, DOI: 10.1007/s00410-012-0783-z.

Baldwin, S.L., Fitzgerald, P.G., and **Webb, L.E.**, 2012, Tectonics of the New Guinea region, Annual Review of Earth and Planetary Sciences, v. 40, p. 495-520, doi: 10.1146/annurev-earth-040809-15254, ***INVITED***.

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, *Taylor, J.P.*, Jalbaa, U., and Minjin, C., 2012, Paleogeographic reconstruction of a late Paleozoic arc collision zone, southern Mongolia, Geological Society of America Bulletin, doi:10.1130/B30510.1.

Webb, L.E., Johnson, C.L., and Minjin, C., 2010, Late Triassic sinistral shear in the East Gobi Fault Zone, Mongolia, Tectonophysics, v. 495, p. 246-255, doi: 10.1016/j.tecto.2010.09.033.

Webb, L.E., Baldwin, S.L., Little, T.A., and Fitzgerald, P.G., 2008, Can microplate rotation drive subduction inversion? Geology, v. 36, p. 823–826.

Baldwin, S.L., **Webb, L.E.**, and Monteleone, B.D., 2008, Late Miocene coesite-eclogite exhumed in the Woodlark Rift, Geology, v. 36, p. 735–738.

Monteleone, B.D., Baldwin, S.L., **Webb, L.E.**, Fitzgerald, P.G., Grove, M., and Schmidt, A.K., 2007, Late Miocene–Pliocene eclogite-facies metamorphism, D'Entrecasteaux Islands, SE Papua New Guinea, Journal of Metamorphic Geology, v. 25, p. 245–265.

Webb, L.E., and Johnson, C.L., 2006, Tertiary strike-slip faulting in southeastern Mongolia and implications for Asian tectonics, Earth and Planetary Science Letters, v. 241, p. 323–335.

Webb, L.E., Leech, M.L., and Yang, T., 2006, $^{40}Ar/^{39}Ar$ thermochronology of the Sulu terrane: Late Triassic exhumation of high and ultrahigh-pressure rocks and implications for Mesozoic tectonics in East Asia, *in* Geological Society of America Special Paper *Ultrahigh-Pressure Metamorphism: Deep Continental Subduction,* edited by B.R. Hacker, B. McClelland, and J.G. Liou, p. 77–92.

Leech, M.L., **Webb, L.E.**, and Yang, T., 2006, Diachronous histories for the Dabie-Sulu orogen from high-temperature geochronology, *in* Geological Society of America Special Paper *Ultrahigh-Pressure Metamorphism: Deep Continental Subduction,* edited by B.R. Hacker, B. McClelland, and J.G. Liou, p. 1–22.

Lewis, A.R., Marchant, D.R., Baldwin, S.L., and **Webb, L.E.**, 2006, The age and origin of the Labyrinth, western Dry Valleys, Antarctica: evidence for extensive middle Miocene subglacial floods and freshwater discharge to the Southern Ocean, Geology, v. 34, p. 513–516.

Fitzgerald, P., Baldwin, S., **Webb, L.E.,** and O'Sullivan, P., 2006, Interpretation of (U-Th)/He single grain ages from slowly cooled crustal terranes: A case study from the Transantarctic Mountains of southern Victoria Land, Chemical Geology, v. 225, p. 91–120.

Baldwin, S.L., *Monteleone, B.*, **Webb, L.E.**, Fitzgerald, P.G., Grove, M and Hill, E.J., 2004, Pliocene eclogite exhumation at plate tectonic rates in eastern Papua New Guinea, Nature, v. 431, p. 263–267.

Ratschbacher, L., Hacker, B.R., Calvert, A., **Webb, L.E.**, Grimmer, J.C., McWilliams, M., Ireland, T.R., Dong, S. and Hu, J., 2003, Tectonics of the Qinling (central China): Tectonostratigraphy, geochronology, and deformation kinematics, Tectonophysics, v. 336, p. 1–53.

Johnson, C.L., **Webb, L.E.**, Graham, S.A., Hendrix, M., and Badarch, G., 2001, Sedimentary and structural records of late Mesozoic high-strain extension and strain partitioning, East Gobi Basin, southern Mongolia, Memoir - Geological Society of America, v. 194, p. 231–246.

Webb, L.E., Ratschbacher, L., Hacker, B.R. and Dong, S., 2001, Kinematics of exhumation of high- and ultrahigh-pressure rocks in the Hong'an and Tongbai Shan of the Qinling–Dabie collisional orogen, eastern China, Memoir - Geological Society of America, v. 194, p. 413–434.

Graham, S.A., Hendrix, M.H., Johnson, C.L., D. Badamgarav, G. Badarch, Amory, J., Porter, M., R. Barsbold, **Webb, L.E.**, Hacker, B., 2001, Sedimentary record and tectonic implications of Mesozoic rifting in southeast Mongolia, GSA Bulletin, v. 113, p. 1560–1579.

Hacker, B.R., Ratschbacher, L., **Webb, L.E.**, McWilliams, M., Calvert, A., Dong, S., Wenk, H.-R., and Chateigner, D., 2000. Exhumation of ultrahigh-pressure rocks in the Dabie-Hong'an area: Late Triassic-Early Jurassic tectonic unroofing, Journal of Geophysical Research, v. 105, p. 13,339–13,364.

Ratschbacher, L., Hacker, B.R., **Webb, L.E.**, Calvert, A., Ireland, T.R., McWilliams, M.O., Dong, S., Chateigner, D., and Wenk, H.-R., 2000. Exhumation of the ultrahigh-pressure continental crust in east-central China: Cretaceous and Cenozoic unroofing and the Tan-Lu Fault, Journal of Geophysical Research, v. 105, 13303–13338.

Lamb, M.A., Hanson, A.D., Graham, S.A., Badarch, G., and **Webb, L.E.**, 1999, Left-lateral sense offset of Upper Proterozoic and Paleozoic features on the Gobi Onon, Tost, and Zuunbayan faults in southern Mongolia and implications for other central Asian faults, Earth and Planetary Research Letters, v. 173, p. 183–194

Webb, L.E., Hacker, B.R., Ratschbacher, L., Michael O. McWilliams, and Dong S., 1999. Thermochronologic constraints on deformation and cooling history of high and ultrahigh-pressure rocks in the Qinling–Dabie orogen, Tectonics, v. 18, p. 621–638.

Webb, L.E., Graham, S.A., Johnson, C.L., Badarch, G., Hendrix, M., 1999. Occurrence, age, and implications of the Yagan–Onch Hayrhan metamorphic core complex, southern Mongolia, Geology, v. 27, p. 143–146.

Hacker, B.R., Ratschbacher, L., **Webb, L.E.**, Ireland, T., Walker, D., and Dong S., 1998. U/Pb Zircon ages constrain the architecture of the ultrahigh-pressure Qinling–Dabie orogen, China, Earth and Planetary Science Letters, v.161, p. 215–230.

Hacker, B.R., Ratschbacher, L., **Webb, L.E.**, and Dong S., 1995. What brought them up? Exhumation of the Dabie Shan ultrahigh-pressure rocks, Geology, v. 23, p. 743–746.

WHITE PAPERS

Crespi, J., Klepeis, K., Williams, M., Thomas, W., **Webb, L.**, Gale, M., Kim, J., and Becker, L., 2011, EarthScope in the New England Appalachians: Structural inheritance and the long-term strength of continental lithosphere. National Science Foundation Joint EarthScope-GeoPRISMS Science Workshop for Eastern North America.

Baldwin, S., Fitzgerald, P., Curewitz, D., Mann, P., Hacker, B., **Webb, L.**, Abers, G., Little, T., Wallace, L., Devey, C., Hoernle, K., Speckbacher, R., and Behrmann, J., 2010, Rift Initiation and Evolution within an Active Plate Boundary Zone: The Woodlark Rift of Papua New Guinea. National Science Foundation GeoPRISMS Rift Initiation and Evolution (RIE) initiative.

PUBLISHED (REFERREED) ABSTRACTS OF CONFERENCE PRESENTATIONS

Student authors indicated in italics

Webb, L.E., 2019. Revelations from EarthScope on the Dynamic History of North America. Association for the Advancement of Science, Annual Meeting, Washington D.C. ***INVITED.***

McGrew, A.J., *Rodgers, A.*, Metcalf, J.R., Mesiner, C.B., and **Webb, L.E.**, 2018. Tracking the escalator ride from mid-crustal depths to the surface: New constraints on the pace and episodicity of late Eocene to Miocene exhumation from the southern east Humboldt Range

metamorphic core complex, Elko County, Nevada. Geological Society of America Abstracts with Programs. Vol. 50, No. 6. doi: 10.1130/abs/2018AM-318419.

Baldwin, S.L., Fitzgerald, P.G., **Webb, L.E.**, Malusa, M.G., and Moucha, R., 2018. How to make and exhume (U)HP terranes: insights from southeastern Papua New Guinea (EOS, Transactions, American Geophysical Union, Fall Meeting). ***INVITED.***

Gonzalez, J., Baldwin, S.L., Thomas, J.B., Fitzgerald, P.G., **Webb, L.E.**, and Kim, J.J., 2018. Peak pressure-temperature-time estimates for Taconic orogen high-pressure rocks, Tillotson Peak Complex, Vermont. (EOS, Transactions, American Geophysical Union, Fall Meeting).

Tam, E., Webb, L.E., and *Aiken, C.*, 2018. Geochronologic Constraints on the Timing of Deformation in the Footwall of the Prospect Rock Fault in North-Central Vermont. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-310928.

Caswell, B., Gilotti, J.A., Webb, L.E., Jones, D.A., McClelland, W.C., 2018. $^{40}Ar/^{39}Ar$ Geochronology of Biotite from Ductile Shear Zones of the Ellesmere-Devon Crystalline Terrane, Nunavut, Canadian Arctic. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-310455

Dundas, E., Ehlers, A., Lee, J., Titsworth, K., Weiss, H., and **Webb, L.E.**, 2018. Use of Ground-Penetrating Radar and Electromagnetic Induction Profiling to Image a Buried Revolutionary War Trench at Chimney Point, Addison County, Vermont. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311041.

Aiken, C.L., and **Webb, L.E.**, 2018. Geochronologic Constraints on the Timing of Metamorphism and Exhumation of the Tillotson Peak Complex in Northern Vermont. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-310829.

Webb, L.E., Klepeis, K.A., and Kim, J.J., 2018. New Insights on Acadian Deformation and Reactivation in Northern Vermont from Integrated Structural and Geochronological Studies. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311032.

Klepeis, K., **Webb, L.E.**, *Merson, M.Q.*, and Kim, J.J., 2018. Unraveling Fault Reactivations and Their Tectonic Significance Using Integrated Structural Data and $^{40}Ar/^{39}Ar$ Geochronology, Examples from N. Vermont and S.W. New Zealand. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311301.

Maguire IV, H.C., Merhtens, C., Chiarenzelli, J., and Webb, L.E., 2018. Detrital Zircon Ages for the Cambrian Monkton and Danby Formations, Champlain Valley, Vermont. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-311008.

Gonzalez, J.P., Baldwin, S., Kim, J.J., and **Webb, L.E.**, 2018. A Comparison of Pressure-Temperature-Time Histories across the Burgess Branch Fault Zone, Northern Vermont. Geological Society of America Abstracts with Programs. Vol. 50, No. 2, doi: 10.1130/abs/2018NE-310874.

Brombin, V., Marzoli, A., Roghi, G., Fred, J., Coltorti, M., Bonadiman, C., **Webb, L.E.**, Sara, C., Giuliano, B., De Vecchi, G. and Roberto, S., 2018. The temporal evolution of the Cenozoic Southalpine magmatic activity in North-East Italy: evidence from $^{40}Ar/^{39}Ar$ geochronology. In European Geosciences Union (pp. 1-1). European Geosciences Union.

Tam, E., **Webb, L.E.**, and *Aiken, C.L.*, 2017, Role of the Prospect Rock Fault in the Exhumation of High Pressure Rocks in North-Central Vermont. (EOS, Transactions, American Geophysical Union).

Klepeis, K., **Webb, L.E.**, Blatchford, H.J., Schwartz, J.J., Turnbull, R., and Jongens, R., 2017. Unraveling a history of repeated fault reactivations and differential uplift above a young subduction zone in SW New Zealand, Geological Society of America Abstracts with Programs. Vol. 49, No. 6, doi: 10.1130/abs/2017AM-306155.

Webb, L.E., 2017. Strange results or: How I learned to stop worrying and love complicated $^{40}Ar/^{39}Ar$ apparent age spectra. Geological Society of America Abstracts with Programs. Vol. 49, No. 6, doi: 10.1130/abs/2017AM-306106.

Cordova, J.L., Schermer, E., Mulcahy, S.R., and **Webb, L.E.**, 2017. Initiation and early evolution of a subduction zone: T-t-D history of the Easton metamorphic suite, northwest Washington State, Geological Society of America Abstracts with Programs. Vol. 49, No. 6, doi: 10.1130/abs/2017AM-303853.

Fitzgerald, P.G., Baldwin, S.L., Bermúdez, M.B., **Webb, L.E.**, Little, T.A., Miller, S.R., Malusà, M.G., Seward, D., 2017. Rift-triggered exhumation of eclogite-bearing gneiss domes in eastern Papua New Guinea: Geologic and thermochronologic constraints. 12th International Eclogite Conference, Åre, Sweden, August 2017.

Aiken, C., and **Webb, L.E.**, 2017. Exhumation of the Tillotson Peak complex in northern Vermont. Northeastern North-Central Joint Section Meeting of the Geological Society of America. Pittsburgh, Pennsylvania.

Brombin, V., **Webb, L.**, Bonadiman, C., Marzoli, A., and Coltorti, M., 2017. A geochronological study of mafic and acidic lavas from Veneto Volcanic province (North-East Italy), EGU General Assembly 2017, Vienna, Austria. Geophysical Research Abstracts, Vol. 19, EGU2017-6410, 2017.

Ebinger, C., Humphreys, E., Williams, M., van der Lee, S., Levin, V., **Webb, L.**, and Becker, T., 2017. Dynamics and the Wilson Cycle: An EarthScope vision. EGU General Assembly 2017, Vienna, Austria. Geophysical Research Abstracts, Vol. 19, EGU2017-5829.

Webb, L.E., Klepeis, K.A., Kim, J., and *Sullivan, P.*, 2017, Reactivation of Taconic Thrust Faults in the Late Acadian Orogenic Front. 2017 EarthScope National Meeting. Anchorage, Alaska.

Mehrtens, C., **Webb, L.E.**, Harrington, S., Desanto, D., and Berman, E., 2016. Writing and Information Literacy in The Geosciences: A Pilot Project to Improve Student Understanding and Communication, Geological Society of America Abstracts with Programs. Vol. 48, No. 7, doi: 10.1130/abs/2016AM-277481.

Tsai, C.-H., Liu, C., **Webb, L.**, and Keyser, W., 2016, New P-T and Geochronological Constraints on High-Pressure Garnet-Bearing Paragonite-Epidote Amphibolite in the Yuli Belt, Eastern Taiwan. Goldschmidt Conference, Yokohama, Japan. Goldschmidt Abstracts, 2016 3180.

Webb, L.E. and Klepeis, K.A., 2015, Punctuated melt-enhanced deformation and tectonic reactivation above a long-lived subduction zone, coastal Andes, central Chile, Geological Society of America Abstracts with Programs. Vol. 47, No. 7, p. 495.

Baldwin, S.L., Malusà, M.G., Fitzgerald, P.G., **Webb, L.E.**, and, 2015, Deciphering the 4-d evolution of Cenozoic (U)HP terranes, Geological Society of America Abstracts with Programs. Vol. 47, No. 7, p. 168. ***INVITED***.

Fitzgerald, P.G., Baldwin, S.L., Bermúdez, M.B., **Webb, L.E.**, Little, T.A., Malusà, M.G., Miller, S.R., and Seward, D., 2015, Constraints from low-temperature thermochronology on exhumation of (U)HP terranes: the eastern Papuan New Guinea example, Geological Society of America Abstracts with Programs. Vol. 47, No. 7, p. 375.

Lagor, S. and **Webb, L.E.**, 2015, Evidence for syntectonic intrusion of the Knox Mountain Pluton in the Connecticut Valley-Gaspe Trough, central Vermont, Geological Society of America Abstracts with Programs. Vol. 47, No. 3, p. 101.

Baldwin, S.L., Fitzgerald, P.G., **Webb, L.E.**, and Malusà, M.G., 2015, The (U)HP terrane of eastern Papua New Guinea: a modern analogue for (U)HP terranes globally, XI International Eclogite Conference, Dominican Republic.

Fitzgerald, P.G., Baldwin, S.L., Bermúdez, M.B., **Webb, L.E.**, Little, T.A., Miller, S.R., Malusà, M.G., and Seward, D., 2014, Exhumation of the Papuan New Guinea (U)HP terrane: Constraints from low temperature thermochronology, XI International Eclogite Conference, Dominican Republic.

Baldwin, S.L., Bermúdez, M., Fitzgerald, P.G., and **Webb, L.E.**, 2014, Integrative thermochronology, petrology and modelling reveal the 4-D evolution of active plate boundary zones, 14th International Conference on Thermochronology, September 2014, Chamonix, France.

Webb, L.E., Klepeis, K.A., Jones, D.A., Webber, J.R., Cembrano, J., Morata, D., Mora-Klepeis, G., and Arancibia, G., 2014, Thermochronologic Constraints on the Late Paleozoic and Early Mesozoic Tectonic Evolution of Coastal Central Chile (33.5 S), Geological Society of America Abstracts with Programs. Vol. 46, No. 6, p.445.

Lagor, S., and **Webb, L.E.**, 2014, The relationship between magmatism, deformation, and metamorphism during the Acadian Orogeny: a case study from the Knox Mountain Pluton, Green Mountains, Vermont, Geological Society of America Annual Meeting, Vancouver, October, 2014.

Webb, L., *Dyess, P., Ashley, K.*, Spear, F., and Thomas, J., 2013, TitaniQ Records of P-T-D Paths from Metapelites during Burial Metamorphism and Orogenesis: Evidence for the Role of Pressure Solution Creep, (EOS, Transactions, American Geophysical Union).

Baldwin, S., Moucha, R., Fitzgerald, P.G., Hoke, G.D., Bermudez, M.A., **Webb, L.E.**, Braun, J., Rowley, D.B., Insel, N., Abers, G.A., Wallace, L.M., and Vervoort., J.D., 2013, Linking mantle dynamics, plate tectonics and surface processes in the active plate boundary zones of eastern New Guinea (EOS, Transactions, American Geophysical Union). ***INVITED***.

Webb, L., *Dyess, P., Ashley, K.*, Spear, F., and Thomas, J., 2013, Probing quartz for P-T-t-D paths, Mineralogical Magazine, 77(5) 2474. Goldschmidt Conference, Florence, Italy.

Ashley K., Law R., Stahr D., Thomas J., Caddick M., Spear F., and **Webb L.**, 2013, Improved Crustal PTtD Evolution Constraints Using TitaniQ Thermobarometry, Mineralogical Magazine, 77(5) 624. Goldschmidt conference, Florence, Italy.

Webb, L.E., Westerman, D.S., Springston, G.E., Kim, J., Klepeis, K., Koteas, G.C., *Ruksnzis, A.*, Merhtens, C., Becker, L.R., and Gale, M., 2013, Field-based undergraduate curriculum and research exploring geophysical methods, with applications to the State of Vermont, (Geological Society of America Northeastern Section – 48th Annual Meeting).

Dyess, P., **Webb, L.E.**, Spear, F.S., and Thomas, J.B., 2012, Investigating Records of Prograde Metamorphism in Quartz with TitaniQ Thermobarometry: Initial Results from the Northfield Mountains, Vermont, (EOS, Transactions, American Geophysical Union).

Thomas, J.B., Spear, F.S., and **Webb, L.E.**, 2012, Experimental study of titanium-in-coesite solubility, (EOS, Transactions, American Geophysical Union).

Baldwin, S.L., Fitzgerald, P.G., Bermudez, M.A., **Webb, L.E.**, Moucha, R., Miller, S.R., *Catalano, J.P.*, and *Zirakparvar, N.A.*, 2012, Linking deep earth to surface processes in the Woodlark Rift of Papua New Guinea; a framework for understanding (U)HP exhumation globally, (EOS, Transactions, American Geophysical Union).

Fitzgerald, P.G., Baldwin, S.L., Bermudez, M.A., Miller, S.R., **Webb, L.E.**, and Little, T., 2012, Low-temperature thermochronologic constraints on cooling and exhumation trends along conjugate margins, within core complexes and eclogite-bearing gneiss domes of the Woodlark rift system of eastern Papua New Guinea, (EOS, Transactions, American Geophysical Union).

Ashley K.T., **Webb, L.E.**, Spear, F.S., and Thomas, J.B., 2012, P-T-D Histories and Reequilibration of Ti in Quartz: Using the TitaniQ Thermobarometer in Poly-Deformed Tectonic Terranes, Mineralogical Magazine, 1436, Goldschmidt conference, Montreal, Quebec, Canada.

Spear, F.S., *Ashley K.T.*, **Webb, L.E.**, and Thomas, J.B., 2012, Tectonic implications of short metamorphic episodes, Goldschmidt Conference, Montreal, Quebec, Canada.

Ruksznis, A., Kim, J., Klepeis, K., and **Webb, L.E.**, 2012, Integration of structural analysis, EMI, and GPR surveys, and hydrogeology in the Plainfield quadrangle, central Vermont, (Geological Society of America Northeastern Section – 47th Annual Meeting).

McNiff, C.M., Klepeis, K., **Webb, L.E.**, and Kim, J., 2012, Geometric variability and spatial extent of an Acadian dome and basin fold interference pattern in NW Vermont, (Geological Society of America Northeastern Section – 47th Annual Meeting).

Webb, L.E., Taylor, J.P., Heumann, M.J., Johnson, C.L., *Stypula, M.J.*, and Kylander-Clark, A.R.C., 2011, Permo-Triassic collisional orogenesis and transition to intraplate sinistral shear in southeastern Mongolia, (EOS, Transactions, American Geophysical Union).

Baldwin, S.L., *Zirakparvar, N.A.*, **Webb, L.E.**, Kula, J., Metcalf, J.R., Fitzgerald, P.G., and *Catalano, J.P.*, 2011, The isotopic record of subduction and exhumation within the (U)HP terrane of Papua New Guinea, 9th International Eclogite Conference, Czech Republic.

Catalano, J.P., Baldwin, S.L., Fitzgerald, P.G., and **Webb, L.E.**, 2011, The isotopic record of subduction and exhumation within the (U)HP terrane of Papua New Guinea, 9th International Eclogite Conference, Czech Republic.

Fitzgerald, P.G., Baldwin, S.L., Miller, S.R., Little, T.A., **Webb, L.E.**, Metcalf, J.R., and Perry, S.E., 2011, Apatite fission track and (U-Th)/He dating in the world's youngest UHP terrane: The Woodlark rift of southeastern Papuan New Guinea, Mineralogical Magazine, p. 852.

Webb, L.E., *Taylor, J.P., Heumann, M.J.*, Johnson, C.L., *Stypula, M.J.*, and *Hagen-Peter, G.A.*, 2010, Thermochronologic Records of Intraplate Deformation in the Northern East Gobi Fault Zone, Mongolia (EOS, Transactions, American Geophysical Union).

Ashley K.T., **Webb, L.E.**, Spear, F.S., and Thomas, J.B., 2010, Constraining P-T-t-D Histories with the TitaniQ Thermobarometer: Preliminary Findings from the Strafford Dome, Vermont (EOS, Transactions, American Geophysical Union).

Stypula, M.J., and **Webb, L.E., 2010**, Microstructural and U-Pb Zircon Constraints on the Relationship between Partial Melting and Ductile Shear in the East Gobi Fault Zone, Southeast Mongolia (EOS, Transactions, American Geophysical Union).

Baldwin, S., *Zirakparvar, N.A., Catalano, J.P.*, Fitzgerald, P.G., **Webb, L.E.**, and Little, T., 2010, Reconstructing the Mid-Miocene to Recent evolution of the Woodlark Rift (EOS, Transactions, American Geophysical Union).

Catalano, J.P., Baldwin, S., Fitzgerald, P.G., **Webb, L.E.**, and Hollocher, K., 2010, Temporal and geochemical constraints on active volcanism in southeastern Papua New Guinea (EOS, Transactions, American Geophysical Union).

Baldwin, S.L., **Webb, L.E.**, Fitzgerald, P.G, *Zirakparvar, N.A.*, and *Catalano, J.P.*, 2010, From subduction to rifting: The Late Cretaceous–Cenozoic tectonic evolution of eastern Papua New Guinea, (Tectonic Crossroads: Evolving Orogens of Eurasia-Africa-Arabia, Ankara, Turkey, Paper No. 32-3), ***INVITED***.

Webb, L.E., Baldwin, S.L., *Zirakparvar, N.A.*, Fitzgerald, P.G, and *Catalano, J.P.*, 2010, From microstructures to microplates: Integrating across scales to constrain the plate boundary evolution in eastern Papua New Guinea (AGU Western Pacific Meeting, V44A-02). ***INVITED***.

Webb, L.E., Baldwin, S.L., Fitzgerald, P.G., *Castellan, L.*, and *Zirakparvar, N.A.*, 2009, Structural Analysis of the Louisiade Archipelago, Southeastern Papua New Guinea (EOS, Transactions, American Geophysical Union).

Taylor, J.P., **Webb, L.E.**, Johnson, C.L., *Heumann, M.J., Hagen-Peter, G.A.*, and Gehrels, G.E., 2009, Testing the Existence of the South Gobi Microcontinent: U-Pb Zircon Dating of Tectonites within the East Gobi Fault Zone, Southeastern Mongolia (EOS, Transactions, American Geophysical Union).

Stypula, M., **Webb, L.E.**, and *Hagen-Peter, G.A.*, 2009, Evidence for partial melting at northern Tavan Har and relationship to Late Triassic sinistral shear in the East Gobi Fault Zone, southeastern Mongolia (EOS, Transactions, American Geophysical Union).

Hagen-Peter, G.A., **Webb, L.E.**, and *Stypula, M.*, 2009, Large-scale folding in the Tavan Har basement block, southeastern Mongolia and its relevance to Phanerozoic intracontinental deformation (EOS, Transactions, American Geophysical Union).

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, *Taylor, J.P.*, 2009, Mesozoic–Cenozoic Reconstruction of the East Gobi Fault Zone, Southern Mongolia (EOS, Transactions, American Geophysical Union).

Taylor, J.P., **Webb, L.E.**, Johnson, C.L., *Heumann, M.J.*, 2009, Strike-slip and exhumation history of the East Gobi Fault Zone, southeastern Mongolia, with emphasis on the Cenozoic era (Geological Society of America *Abstracts with Programs*, Geological Society of America Abstracts with Programs).

Taylor, J.P., **Webb, L.E.**, Fitzgerald, P.G., Johnson, C.L., *Heumann, M.J.*, 2008, Constraints on the Low Temperature Thermal History of the Tsagan Subarga and Tavan Har Basement Blocks of the East Gobi Fault Zone, Southeastern Mongolia, and Tectonic Implications (EOS, Transactions, American Geophysical Union).

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, *Taylor, J.P.*, 2008, Detrital zircon and sandstone provenance analysis from Permian and Lower Cretaceous sedimentary units to constrain total and incremental left-lateral offset along the East Gobi Fault Zone, southeastern Mongolia (EOS, Transactions, American Geophysical Union).

Baldwin, S.L., Little, T.A., **Webb, L.E.**, Fitzgerald, P.G., *Zirakparvar, A.* and *Peters, K.*, 2008, Metamorphic Core Complex Formation on Misima Island during Miocene-Pliocene Rifting and Seafloor Spreading in the Woodlark Basin, Papua New Guinea, SE Papua New Guinea (EOS, Transactions, American Geophysical Union).

Waggoner, A.G., Baldwin, S.L., **Webb, L.E.**, Little, T.A., and Fitzgerald, P.G., 2008, Temporal Constraints on Continental Rifting and the Exhumation of Pliocene Eclogites, SE Papua New Guinea (EOS, Transactions, American Geophysical Union).

Fitzgerald, P.G., Baldwin, S.L., Miller, S.R., *Perry, S.E.*, **Webb, L.E.**, and Little, T.A., 2008, Low-Temperature Constraints on the Evolution of Metamorphic Core Complexes of the Woodlark Rift System, Southeastern Papua New Guinea (EOS, Transactions, American Geophysical Union).

Webb, L.E., Baldwin, S.L., Little, T.A., and Fitzgerald, P.G., 2008, Is Microplate Rotation Driving HP–UHP Exhumation in Eastern Papua New Guinea? (Geological Society of America *Abstracts with Programs*, Geological Society of America Abstracts with Programs, v. 40, n. 6, p. 551). ***INVITED***.

Webb, L.E., Johnson, C.L., Minjin, C., 2007, Thermochronology of early Mesozoic shear in the East Gobi Fault Zone, Mongolia (EOS, Transactions, American Geophysical Union).

Taylor, J.P., **Webb, L.E.**, Johnson, C.L., *Heumann, M.J.*, 2007, Constraints on Mesozoic and Tertiary Brittle Faulting in the Southern East Gobi Fault Zone, Southeastern Mongolia (EOS, Transactions, American Geophysical Union).

Semple, I.L., **Webb, L.E.**, *Taylor, J.P., Heumann, M.J.*, Johnson, C.L., Minjin, C., 2007, Early Mesozoic overprinting of Paleozoic protoliths during shear zone formation in the southeast Gobi, Mongolia (EOS, Transactions, American Geophysical Union).

Heumann, M.J., Johnson, C.L., **Webb, L.E.**, *Taylor, J.P.*, 2007, Implications for Mesozoic to Modern Tectonic Deformation in Sub-Basins Along the East Gobi Fault Zone, Southern Mongolia (EOS, Transactions, American Geophysical Union).

Baldwin, S.L., **Webb, L.E.,** *Monteleone, B.D.*, 2007, Late Miocene coesite-eclogite exhumed in the Woodlark Rift, Papua New Guinea (EOS, Transactions, American Geophysical Union).

Beamud, E., Fitzgerald, P., Muñoz, J., Garces, M., Baldwin, S., Webb, L., *Schwabe, E.*, and Cabrera, L., 2007 Palaeogene Exhumation of the Pyrenean Orogen: Magnetostratigraphic and Thermochronological Constraints from the South-Central Pyrenees (EOS, Transactions, American Geophysical Union).

Webb, L.E., and Johnson, C.L., 2006, Intraplate Deformation Phase I of the East Gobi Fault Zone, Mongolia: Early Mesozoic Sinistral Shear (Geological Society of America *Abstracts with Programs*, Geological Society of America Abstracts with Programs, v. 38, n. 7, p. 418).

Baldwin, S.L., *Monteleone, B.D.*, Little, T.A., **Webb, L.E.**, and Fitzgerald, P.G., 2006, Subduction to rifting evolution of the Australian–Woodlark plate boundary zone of eastern Papua New Guinea: insights into the 4-D nature of continental subduction and exhumation processes (Geological Society of America *Abstracts with Programs*, v. 38, n. 7, p. 274).

Webb, L.E., Johnson, C.L., G. Badarch, Ch. Minjin, G. Sersmaa, 2006, Evidence for an early Mesozoic mylonitic sinistral shear zone in southeastern Mongolia, IGCP 480 (International Geological Congress), Structural and Tectonic Correlation across the Central Asia Orogenic Collage, Ulaanbaatar, Mongolia, July 2006, Extended Abstracts Volume, p. 43-45.

Johnson, C.L., Amory, J.A., Zinniker, Z., Lamb, M.A., G. Badarch, and **Webb, L.E.**, 2006, Sedimentary record of arc collision, Permian, southern Mongolia, IGCP 480 (International Geological Congress), Structural and Tectonic Correlation across the Central Asia Orogenic Collage, Ulaanbaatar, Mongolia, July 2006, Extended Abstracts Volume, p. 46-49.

Baldwin, S.L., **Webb, L.E.**, *Monteleone, B.*, Little, T.A., Fitzgerald, P.G., *Peters, K.*, Chappell, J.L., 2006, Continental crust subduction and exhumation: Insights from eastern Papua New Guinea, Geochimica et Cosmochimica Acta Supplement, v. 70, issue 18, p. 31.

Baldwin, S.L., **Webb, L.E.**, and Monteleone, B., Little, T.A., Fitzgerald, P.G., and Chappell, J.L., 2005, Metamorphism and exhumation of the youngest known HP/UHP terrane on Earth, eastern Papua New Guinea, (EOS, Transactions, American Geophysical Union; v. 86 (52)).

Leech, M.L., **Webb, L.E.**, and Yang, T., 2005, Diachronous histories for the Dabie-Sulu orogen from high-temperature geochronology (Geological Society of America *Abstracts with Programs*, v. 37, n. 7, p. 57)

Affolter, M.D., Johnson, C.L., and **Webb, L.E.**, 2005, Tectonic History of the East Gobi Basin (Geological Society of America *Abstracts with Programs*, v. 37, n. 7, p. 442).

Fitzgerald, P., Baldwin, S., Muñoz, J.-A., **Webb, L.**, and *Schwabe, E.*, 2005, Exhumation of the Pyrean intracontinental collisional orogen: New thermochronologic constraints from the central Pyrenees (Geological Society of America *Abstracts with Programs*, v. 37, n. 7, p. 346)

Webb, L.E., Baldwin, S.L., Little, T.A., and Fitzgerald, P.G., 2005, A pivoting microplate model for subduction eversion and exhumation of UHP terranes (7th International Eclogite Conference, Austria, Mitt.Österr.Miner.Ges. 150, p. 164).

Baldwin, S.L., **Webb, L.E.**, and *Monteleone, B.*, 2005, Late Miocene–Pliocene eclogites of eastern Papua New Guinea: the youngest known HP/UHP terrane on Earth (7th International Eclogite Conference, Austria, Mitt.Österr.Miner.Ges. 150, p.16).

Monteleone, B., Baldwin, S., **Webb, L.** & Fitzgerald, P., 2005, Constraints on Eclogite Facies Metamorphism in Southeastern Papua New Guinea from in situ Ion Microprobe U-Pb and REE Analyses (15th Annual Goldschmidt Conference, Abstract Volume, A60).

Johnson, C.L., and **Webb, L.E.**, 2005, Cenozoic Reactivation of the East Gobi Fault Zone, 20th Symposium, Himalaya-Karakorum-Tibet Workshop (HKT20), Aussois, France, (Geologie Alpine, Memoire H.S., n. 44, p.94-95).

Webb, L.E., Johnson, C.L., Minjin, Ch., Sersmaa, G., Affolter, M., and Manchuk, N, 2004, Mesozoic and Cenozoic Intracontinental Deformation in Southeastern Mongolia, (EOS, Transactions, American Geophysical Union, v. 85 (47), F1698).

Johnson, C.L., **Webb, L.E.**, Minjin, Ch., Sersmaa, G., *Affolter, M.*, and *Manchuk, N*., 2004, Sedimentary Basin Evolution in the Context of Polyphase Intracontinental Deformation: New Insights from Southeastern Mongolia, (EOS, Transactions, American Geophysical Union; v. 85 (47), F1699).

Baldwin, S.L., Finn, C.A., **Webb, L.E.**, Fitzgerald, P.G., Little, T., and Anderson, E., 2004, Microplate rotation leads to rapid exhumation of a subduction complex in eastern Papua New Guinea (EOS, Transactions, American Geophysical Union; v. 85 (47), F1738).

Monteleone, B., Baldwin, S.L., Little, T., Fitzgerald, P.G., and **Webb, L.E.**, 2004, Thermochronologic and Geochemical Investigations of High Pressure Metamorphism and Pliocene Exhumation of the D'Entrecasteaux Islands, Southeastern Papua New Guinea (EOS, Transactions, American Geophysical Union; v. 85 (47), F1737).

Baldwin, S.L. **Webb, L.E.**, and Fitzgerald, P.G., 2004, Rifting of a subduction complex in eastern Papua New Guinea leads to exhumation of Pliocene HP rocks at plate tectonic rates (32nd International Geologic Congress, Florence, Italy, August 2004).

Leech, M.L., **Webb, L.E.**, Yang, T., Xu, Z., 2003, Microstructural analysis of the ultrahigh-pressure Sulu Terrane, eastern China (EOS, Transactions, American Geophysical Union; v. 84, F1391).

Baldwin, S.L. P.G. Fitzgerald, T.A. Little, **L.E. Webb** and *B.D. Monteleone*, 2003, Exhumation of the youngest HP rocks, at plate tectonic rates, during Plio-Pleistocene continental extension in SE Papua New Guinea (Geological Society of America *Abstracts with Programs*, v. 35, no. 6, p. 556).

Webb, L.E., Leech, M.L., Yang, T., Xu, Z., 2002, Kinematics of structures of the ultrahigh-pressure Sulu Terrane, eastern China (EOS, Transactions, American Geophysical Union; v. 83, F1245).

Fitzgerald, P., Baldwin, S., Farley, K., Hedges, L., O'Sullivan, P. and **Webb., L.,** 2002, Constraining landscape evolution of the West Antarctic rift flank of southern Victoria Land (Abstracts of the 12th annual V. M. Goldschmidt conference, Geochimica et Cosmochimica Acta v. 66, no. 15A, p. 235).

Fitzgerald, P.G., Baldwin, S.L., Farley, K.A., Hedges, L., O'Sullivan, P.B., and **Webb, L.E**., 2001, Exhumation of apatite helium partial retention zones: An example from the Transantarctic Mountains and implications for (U/Th)/He dating of apatites (Geological Society of America *Abstracts with Programs*, v. 33).

Ritts, B.D., Graham, S.A., **Webb, L.E.**, Chang, E., Hanson, A., Johnson, C.L., 2000, Late Mesozoic Extrusion Tectonics of the North China Block (EOS, Transactions, American Geophysical Union; v. 81).

Anderson, K.S., and others, 1998, The Wagon Rock Project; an interdisciplinary characterization of sand-rich, high-density turbidity current deposits of the "Merle Formation", northern Santa Lucia Range, California (American Association of Petroleum Geologists annual meeting, Salt Lake City, Utah).

Hendrix, M.S., Beck, M. A., Lenegan, R., Graham, S. A., Johnson, C. J., **Webb, L**., and Sjostrom, D. J., 1998, Early Mesozoic development of a regional lake system in southern Mongolia: American Association of Petroleum Geologists National Meeting, Salt Lake City, Utah.

Hendrix, M.S., Beck, M.A., Graham, S. A., Johnson, C. J., and **Webb, L.**, 1998, Early Mesozoic development of a regional lake system in southern Mongolia - sedimentary signature of a collisional foreland style basin? Yinshan-Yanshan major thrust and nappe structures field conference, May 8-11, Hohhot, Nei Mongol, China.

Greene, T.J., Ritts, B.D., **Webb, L.E.**, Graham, S.A.; Johnson, C.L., Hourigan, J.L., 1997. Progress report on Mesozoic Asian studies conducted by Stanford University (Geological Society of America *Abstracts with Programs*, v. 29).

Hacker, B.R., Ratschbacher, L., **Webb, L.E.**, Ireland, T., Walker, D., Calvert, A., Dong, S., 1997. New Constraints on Exhumation of Ultrahigh-Pressure Rocks, Dabie–Hong'an–Tongbai Shan, China (Geological Society of America *Abstracts with Programs*, v. 29).

Johnson, C.L., Graham, S.A., **Webb, L.E.**, Badarch, G., Hendrix, M., Sjostrom, D., Beck, M., and Lenegan, R., 1997. Sedimentary response to late Mesozoic extension in southern Mongolia (EOS, Transactions, American Geophysical Union; v. 78). *INVITED.*

Webb, L.E., Graham, S.A., Johnson, C.L., Badarch, G., Hendrix, M., Sjostrom, D., Beck, M., and Lenegan, R., 1997. Characteristics and implications of the Onch Hayrhan metamorphic core

complex of southern Mongolia (EOS, Transactions, American Geophysical Union; v. 78). ***INVITED.***

Webb, L.E., Hacker, B.R., Ratschbacher, L., Leech, M. Dong, S., and Lianhong, P., 1997. Mesozoic tectonism in the Qinling–Dabie collisional orogen: New constraints on the multistage exhumation of ultrahigh-pressure rocks (Geological Society of America *Abstracts with Programs*, v. 29). ***INVITED.***

Webb, L.E., Hacker, B.R., Ratschbacher, L., and Dong S., 1996. Structures, and kinematics of exhumation; ultrahigh-pressure rocks in the Hong'an Block of Qinling–Dabie Orogen, China (Geological Society of America *Abstracts with Programs*, v. 28).

Webb, L.E., Hacker, B.R., Ratschbacher, L., and Dong S., 1996. Structural and geochronological constraints on the exhumation of high- and ultrahigh-pressure rocks in the Qinling–Dabie Orogen, China. (Penrose Conference: Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion. Penrose Conference, Greece.)

Hacker, Bradley R., Ratschbacher, L., **Webb, L.E.**, and Dong S., 1995, What brought them up? Exhumation of ultrahigh-pressure rocks in the Dabie Mountains of eastern China. (EOS, Transactions, American Geophysical Union; v. 76).

Webb, L.E., Hacker, B.R., Ratschbacher, L., and Dong S., 1995, Structures and kinematics of exhumation from 40 km; the Dabie Shan ultrahigh-pressure rocks, E. China (Geological Society of America *Abstracts with Programs*, v. 27).

GRADUATE ADVISING

Kristin Schnalzer (BS SUNY Plattsburgh), University of Vermont, MS in Geology, 2020 expected. Investigating the timing of deformation in the Chester Dome with $^{40}Ar/^{39}Ar$ geochronology.

Cheyne Aiken (BS SUNY Potsdam), University of Vermont, MS in Geology, October 2018. Geochronologic Constraints on the Timing of Metamorphism and Exhumation of the Tillotson Peak Complex in Northern Vermont.

Evan Tam (BS University of Connecticut), University of Vermont, MS in Geology, October 2018. Geochronological Constraints on the Timing of Deformation: An Examination of the Prospect Rock Fault Footwall in North-Central Vermont.

Samuel Lagor (BS St. Lawrence University), University of Vermont, MS in Geology, May 2016. The relationship between magmatism, deformation, and metamorphism during the Acadian orogeny: A case study from the Knox Mountain pluton, Green Mountains, Vermont.

Patrick Dyess (BS Montana State University), University of Vermont, MS in Geology, October 2013. Interpreting Quartz Textures through TitaniQ Thermobarometry of Low Grade Metapelites, Northfield Mountains, Vermont. Went on to work with NTL Engineering and Geoscience, Inc.

Christine Downs (BS Salem State University), University of Vermont, MS in Geology, October 2012. The Characterization of Ductile Deformation in the Upper and Lower Plates of the Hinesburg Thrust Fault Through Detailed Geometric Analysis of Selected Outcrops. Currently a PhD student at University of Southern Florida.

Merril Stypula (BA Colorado College), University of Vermont, MS in Geology, May 2012. U-Pb Zircon Dating of Metamorphic Tectonites from Tavan Har, Southeast Mongolia: Implications for the Role of Tectonic Inheritance in Intraplate Shear Zones. Currently employed by EQT Corporation.

Kyle Ashley (BS SUNY Potsdam), University of Vermont, MS in Geology, October 2011. TitaniQ Thermobarometry of Fabric Development in the Strafford Dome, Vermont: Linking Microstructures to Orogenic Processes. Went on to a PhD program at Virginia Tech, post-doc at UT Austin, and now a visiting professor at University of Pittsburgh.

Joshua Taylor, (BS St. Lawrence University, MS Syracuse University), Syracuse University, PhD in Earth Sciences (co-advisor with P.G. Fitzgerald), May 2011. Tectonic History of the East Gobi Fault Zone, Southeastern Mongolia: An Integrated Study Using Structural Geology, Geochronology, and Thermochronology. Currently employed at ExxonMobil Exploration Company.

GRADUATE STUDENT THESIS COMMITTEES

John Mark Brigham, Syracuse University, Department of Earth Sciences. MS, 2019 expected. Mineralogy of the Partially Serpentinized Meta-Dunite in East Dover, Vermont. Advisor: Suzanne Baldwin.

Joseph Gonzales, Syracuse University, Department of Earth Sciences. PhD, 2019 expected. Petrology and Thermochronology of the Burgess Branch Fault Zone at the Tillotson Peak Complex, Vermont. Advisor: Suzanne Baldwin.

Caswell, Brandon, University of Idaho, MS, 2018. $^{40}Ar/^{39}Ar$ Geochronology of Biotite from Ductile Shear Zones of the Ellesmere-Devon Crystalline Terrane, Nunavut, Canadian Arctic. Advisor: Jane Gilotti.

Matthew Merson, University of Vermont, Department of Geology, MS, 2018. The Spatial and Temporal Development of the Champlain Thrust Fault Zone Exposed in Northwest Vermont. Advisor: Keith Klepeis.

Maquire IV, Henry, MS, 2018. Application of Geostatistical and Geochronological Methods to Stratigraphic Problems in the Lower Cambrian Monkton Formation. Advisor: Charlotte Mehrtens.

Julia Runcie, University of Vermont, Ecological Planning Program, Rubenstein School of Environment and Natural Resources. MS, 2017. Environmental assessment guiding recreation at Travertine Hot Springs ACEC. Advisor: Dean Wang

Gina Accorsi, University of Vermont, Department of Geology, MS, 2017. Geochemical and XRD fingerprinting of conflict minerals, Advisor: John M. Hughes.

Mike Ingram, University of Vermont, Department of Geology, MS, 2016. The Effects of Heterogeneity in the Lower Crust on Strain Partitioning and Fabric Development During Extension Doubtful Sound, New Zealand. Advisor: Keith Klepeis.

John Gilbert, University of Vermont, Department of Geology, MS, 2016 expected. Crustal deformation during arc-flare up magmatism: Field and microstructural analysis of a mid-crustal, melt-enhanced shear zone. Advisor: Keith Klepeis.

Hannah Blatchford, University of Vermont, Department of Geology, MS, 2016. Fiordland, New Zealand. The Structural Evolution of a Portion of the Median Batholith and Its Host Rock in Central Fiordland, New Zealand: Examples of Partitioned Transpression and Structural Reactivation. Advisor: Keith Klepeis.

Benjamin Melosh, McGill University, Department of Earth and Planetary Sciences, PhD, 2015. Earthquake cycling in the brittle-plastic transition of a transform boundary: The Pofadder Shear Zone, Namibia and South Africa. Advisor: Christie Rowe.

Myagmarjav Lkhagvasuren, University of Vermont, Wildlife and Fisheries Biology Program Rubenstein School of Environment and Natural Resources, MS, 2015. Effects of Landscape Characteristics on Carnivore Diversity in Mongolia. Advisor: James Murdoch.

Ryan Brink, University of Vermont, Department of Geology, MS, 2014. Sedimentologic Comparison of the Late/Lower Early Middle Cambrian Altona Formation and the Lower Cambrian Monkton Formation. Advisor: Char Mehrtens.

Kathryn Dianiska, University of Vermont, Department of Geology, MS, 2014. The Interplay Between Deformation and Metamorphism During Strain Localization in the Lower Crust: Insights from Fiordland, New Zealand. Advisor: Keith Klepeis.

Alice Newman, University of Vermont, Department of Geology, MS, 2014. Strain Localizaton and Exhumation of the Lower Crust: A Study of the Three-Dimensional Structure and Flow Kinematics of Central Fiordland, New Zealand. Advisor: Keith Klepeis.

Jacob Menken, University of Vermont, Department of Geology, MS, 2014. Effect of Thermal Treatment on the Cation Exchange and Disordering in Tourmaline. Advisor: John Hughes.

Stephanie Perry, Syracuse University, Department of Earth Sciences, PhD, 2014. Thermotectonic Evolution of the Alaska Range: Low-temperature Thermochronologic Constraints. Advisor: Paul Fitzgerald.

Jeffrey Webber, University of Vermont, Department of Geology, MS, 2012. Advances in Rock Fabric Quantification and the Reconstruction of Progressive Dike Emplacement in the Coastal Batholith of Central Chile. Advisor: Keith Klepeis.

Jessica Terrien, Syracuse University, Department of Earth Sciences, PhD, 2012, dissertation in progress. Thermochronology and Geophysical Modeling of the Santa Catalina Metamorphic Core Complex, Arizona. Advisor: Suzanne Baldwin.

Charles Trodick, University of Vermont, Department of Geology, MS, 2011. Sediment Generation Rates in the Potomac River Basin. Advisor: Paul Bierman.

Eric Portenga, University of Vermont, Department of Geology, MS, 2010. Using ^{10}Be to constrain erosion rates of bedrock outcrops globally and in the central Appalachian Mountains. Advisor: Paul Bierman.

Janelle McAtamney, University of Vermont, Department of Geology, MS, 2010. Synthesizing the tectonic evolution of the Magallanes foreland basin during the Late Cretaceous backarc basin inversion using structural and stratigraphic evidence from Bahia Brookes, southern Patagonia, Chile. Advisor: Keith Klepeis.

Matthew Heumann, University of Utah, Department of Geology and Geophysics, PhD, 2010. Tectonic history and subsequent basin development along the East Gobi Fault Zone in southeastern Mongolia. Advisor: Cari Johnson.

Brian Monteleone, Syracuse University, Department of Earth Sciences, PhD, 2006. Timing and conditions of formation of the D'Entrecasteaux Islands, Southeastern Papua New Guinea. Advisor: Suzanne Baldwin.

ADVISING OF UNDERGRADUATE RESEARCH

Eryka Collins and John Sawyer Shaw, Geology BS, 2019 expected. Microstructural analyses and $^{40}Ar/^{39}Ar$ geochronology of the Rattlesnake Thrust, southern Vermont.

Samantha Portnoy, Geology BS, 2018. Relationship between rapid exhumation and fault patterns in Fiordland, New Zealand. Co-advising with Keith Klepeis.

Patrick Sullivan, University of Vermont, Geology BS, 2017. Structural analysis and geochronology of pseudotachylyte in the Taconic Arrowhead Mountain thrust fault zone.

Elizabeth Pidgeon, University of Vermont, Geology BS, 2017. Subduction–exhumation-related deformation of high-pressure rocks, Tillotson Peak, Vermont.

Mariah Schneider, University of Vermont, Geology, BS, 2016. Geo-archaeological investigation of the UVM Green using ground penetrating radar, electromagnetic induction, and seismic refraction profiling.

Edward Bonner, University of Vermont, Geology, BS, 2016. Geo-archaeological investigation of the UVM Green using ground penetrating radar, electromagnetic induction, and seismic refraction profiling.

Carson Mitchell, University of Vermont, Geology, Geology BS, 2016. Field investigation of the Arrowhead Mountain Thrust Fault in the Lamoille River region.

Andrew Goff, University of Vermont, Geology, BS, 2015. Acadian Deformation in the Connecticut Valley Trough: Investigating Penetrative S_2 Foliation Development in the Waits River Formation.

Jacob Vincent, University of Vermont, Geology, BS, 2014. Structural analysis of Acadian deformation the Dog River Fault Zone, Montpelier, Vermont.

Stefan Christie, University of Vermont, Geology, BS, 2014. Geophysical investigation of the Kent Island Formation within the Blackwater National Wildlife Refuge and the potential influence of glacioisostatic adjustment on the Mid-Atlantic. This project is in collaboration with Ben DeJong, UVM PhD student.

Karina Heffernan, University of Vermont, Geology, BS, 2014. Geological and geophysical investigations of possible karst structures in the Dunham Dolomite, Starksboro, Vermont. This project is in collaboration with the Vermont Geological Survey.

Parker Richmond, University of Vermont, Geology, BS, 2013. Ground-penetrating radar investigation of fractures at Shelburne Point and Mount Philo, Vermont. Field studies advised in Summer and Fall 2012, Spring 2013.

James Christiansen, University of Vermont, Geology, BS, 2012. Metamorphism of arc and forearc lithologies at Tavan Har, SE Mongolia. Spring 2012.

Nick Archer, University of Vermont, Environmental Sciences, BS, 2012. Electromagnetic induction profiling of the Waits River Formation in Calais and East Montpelier, Vermont. Fall 2011. This project is in collaboration with the Vermont Geological Survey.

Ted Crook, University of Vermont, Department of Geology, BS, 2011. Groundwater investigation in Craftsbury, Vermont, using integrated geophysical technologies. Fall 2010–Spring 2011. This project was in collaboration with the Vermont Geological Survey.

Michael Ingram, University of Vermont, Department of Geology, BS, 2011. Interpretation of a Simple Bouguer Gravity Anomaly in Chittenden County, Vermont. Advising period: Fall 2010–Spring 2011. This project was in collaboration with the Vermont Geological Survey and Norwich University. Mike is currently an MS student in the Department of Geology at the University of Vermont.

Hagen-Peter, Graham, University of Vermont, Department of Geology, BS, 2010. “Large Scale Folding in the Tavan Har Basement Block, Southeastern Mongolia: Implications for Intracontinental Deformation”. Advising period: Summer 2009–Spring 2010. Research presented at 2009 American Geophysical Union Fall Meeting, 2010 UVM Student Research

Conference and Spring 2010 Vermont Geological Society Meeting. Graham is currently a PhD student at the Institute for Crustal Studies, University of California, Santa Barbara.

Hefferon, Donald, University of Vermont, Department of Geology, BS, 2011. "Petrographic and Geochemical Analysis of Basement Rocks in the East Gobi Fault Zone, Mongolia." Advising period: Fall 2009–Spring 2010. Research presented at the 2010 Vermont Geological Society Meeting.

Gladstein, Katie, University of Vermont, Department of Geology, BS, 2009. "Volcanic Deformation Analysis of Mount Etna, Sicily, 2007–2008". Advising period: Spring 2009. Field data collected by K. Gladstein was under the supervision of John Murray at The Open University, United Kingdom. Research presented at the 2009 UVM Student Research Conference and Spring 2009 Vermont Geological Society Meeting.

Semple, Ian, Syracuse University, Department of Earth Sciences, BS, Spring 2008. "Early Mesozoic overprinting of Paleozoic protoliths during shear zone formation in the southeast Gobi, Mongolia". Advising period: Summer–Fall 2007. Supported by National Science Foundation Research Experience for Undergraduates supplement to grant EAR-0537165.

EXHIBIT B

Previous Four Years of Expert Testimony for Laura Webb, Ph.D.

Dr. Laura Webb has not testified as an expert at trial or by deposition during the previous four years.